GEOLOGY OF THE CAVE IN ROCK QUADRANGLE

STUART WELLER

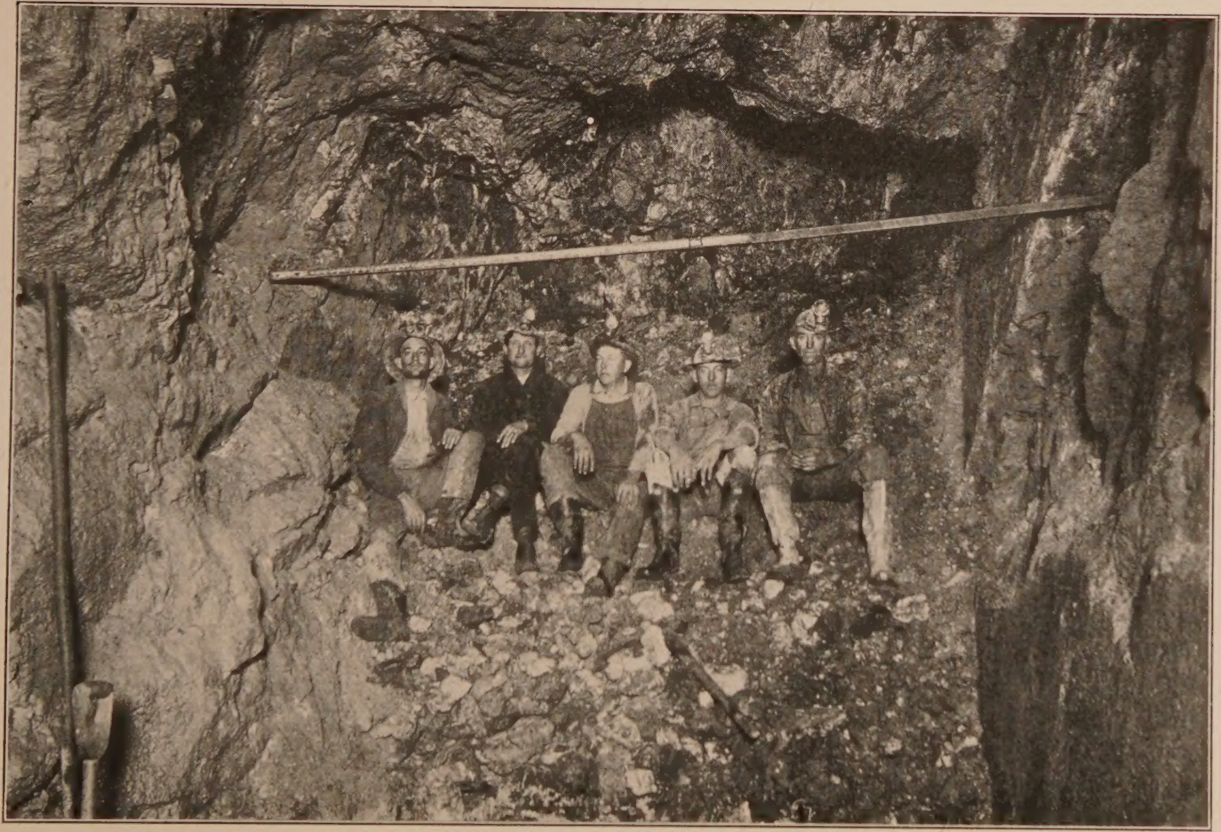
The
Kentucky Geological Survey

WILLARD ROUSE JILLSON
DIRECTOR and STATE GEOLOGIST

SERIES VI
VOLUME TWENTY-SIX

Geology of the Cave in Rock Quadrangle and other Papers

1927



BIG FOUR FLUORSPAR MINE

Underground view showing the width of fractured fault zone which has become mineralized. (Photograph by A. H. Reed.)

GEOLOGY OF THE CAVE IN ROCK QUADRANGLE

A Detailed Report on the Stratigraphy Structure and Areal Distribution of the Rocks South of the Ohio River and in the Vicinity of Marion, Kentucky

BY
Stuart Weller
Assistant Geologist

Presented with Five Separate Miscellaneous Papers
BY
JAMES H. GARDNER
WILBUR GREELEY BURROUGHS
JAMES S. HUDNALL
LEWIS CASS ROBINSON *and*
LUCIEN BECKNER

FIRST EDITION
1500 COPIES

THE KENTUCKY GEOLOGICAL SURVEY
FRANKFORT, KY.

1927

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Frankfort, Ky.

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PREFACE

Interest in the Geology and Mineral Resources of Kentucky continues to grow. This is as it should be for Kentucky holds within her boundary many minerals which are necessary to the life and prosperity of the Nation and the World. Cases in point are those of the Fluorspar deposits of Western Kentucky, and the coals of Eastern Kentucky, the geology of both of which is described in some detail for restricted areas in this volume.

In the educational institutions of Kentucky, particularly the universities, colleges and normal schools, there is an awakened interest in the general geology and the economic geography of Kentucky that was not known a decade or more ago. Such a demand for basic information of an accurate nature augurs well for a new day in Kentucky when an informed and aggressive citizenship shall take from beneath our hills and valleys hidden mineral wealth of large amount, and convert it into a new prosperity statewide in extent. This volume has been prepared and is presented by the Kentucky Geological Survey as a part of a program leading to this end.

W. R. Jillson

Frankfort, Ky.
March 1, 1927.

Director and State Geologist,
Kentucky Geological Survey.

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GEOLOGY OF THE CAVE IN ROCK QUADRANGLE

BY

Stuart Weller
Assistant Geologist

LETTER OF TRANSMISSION

Dr. W. R. Jillson,
Director and State Geologist,
The Kentucky Geological Survey,
Frankfort, Kentucky.

Dear Sir:

I am transmitting herewith the manuscript of a report on the stratigraphic and structural geology of the Cave in Rock quadrangle of the United States Geological Survey topographic atlas.

This is the third of a series of quadrangle reports in western Kentucky, which are designed to describe the geology of the completely faulted area in which are found the rich deposits of fluorspar. The present report covers the area in Crittenden County centering about the city of Marion, in which many of the productive mines are located. It is believed that the more accurate delineation of the fault structures of this region, and the description of the stratigraphic succession of rock formations will prove to be of great benefit in the development of the district.

Respectfully submitted,

STUART WELLER,

Assistant Geologist.

February 1, 1925.
University of Chicago,
Chicago, Ill.

GEOLOGY OF THE CAVE IN ROCK QUADRANGLE

By

Stuart Weller,

Assistant Geologist.

CHAPTER I

INTRODUCTION

The Cave in Rock quadrangle of the United States Geological Survey Topographic Atlas lies between longitude 88° 00′ and 88° 15′, and between latitude 37° 15′ and 37° 30′. It covers about 235 square miles. A little more than 20 square miles lies north of the Ohio River in Illinois. The greater portion of the Kentucky part of the quadrangle is included in Crittenden County, but in the southwestern corner there are about 5½ square miles in Livingston County, and in the southeastern corner about 1½ square miles in Caldwell County. Not the whole of Crittenden County is included in the map, the borders of the county extending to the north, east, south and west beyond the limits of the quadrangle.

The city of Marion, the county seat of Crittenden County, with about 2,000 inhabitants, is situated within the limits of the quadrangle. Smaller towns are Crayne, Salem, and Tolu, and still smaller ones are Levias, Sheridan, Repton, Fords Ferry and Weston. The Evansville-Princeton branch of the Illinois Central Railroad traverses the eastern portion of the quadrangle in a general north-south direction. A number of public highways in the quadrangle have been or are being improved, all of which center in Marion. One of these roads leads to Princeton, one to Paducah, and one to Henderson.

No large water courses except the Ohio River cross the quadrangle, the drainage being accomplished through comparatively small streams. Camp Creek, Crooked Creek, Hurricane Creek and Caney Fork lie wholly within the quadrangle and are tributary to the Ohio River. The headwaters of Coefield Fork of Deer Creek, another tributary of the Ohio River also lie within the area. In the southern part of the quadrangle are the headwaters of Clay Lick Creek and Livingston Creek which are tributary to the Cumberland River, and in the east are Piney Creek and Butler Creek whose waters find their way into the Tradewater River.

Much of the productive area of the fluorspar, lead and zinc mining district of western Kentucky lies within the Cave in Rock quadrangle, some of the better known mines which have been productive in the past or which are productive at the present time being the Columbia the Mary Belle, the Franklin, the Ada Florence, the Keystone, the Old Jim, the Memphis, the Beard, the Commodore, the Big Four, the Crystal, the Holley, the Miller, the Corn and the Lucile Mines.

Throughout the area of the quadrangle the rocks are much faulted, no less than 125 distinct faults being indicated upon the accompanying map, the dislocations varying up to a maximum of nearly 2,000 feet. The type of structure which is present is the same as that which has been described in the Golconda and Princeton quadrangles, the first of which lies directly west of the Cave in Rock quadrangle, and the second of which corners with the southeast corner of the Cave in Rock. All of these quadrangles, along with a considerable adjoining area are parts of a much larger structural unit which extends northward and westward into southern Illinois. The known igneous dikes which are scattered throughout this whole area are more numerous in the Cave in Rock quadrangle than in any of the neighboring ones.

As was done in the report on the Princeton quadrangle, the nine five-minute rectangles of the Cave in Rock quadrangle may be designated by geographic names for convenience in place location. The northeastern corner may be called the Weston rectangle, next west of that is the Fords Ferry rectangle, which in turn is followed by the Tolu rectangle. South of the Tolu is the Sheridan rectangle, next east of that the Crittenden Springs, and east of that the Marion rectangle. South of the Marion is the Crayne, next west the Cisco, and beyond that in the southwestern corner of the quadrangle, the Salem rectangle.

The field work upon which the present report is based was carried on during a portion of the summer of 1922 when the writer was ably assisted by Mr. Ben B. Cox, and through the entire field season in 1923 with the assistance of Mr. E. D. Phillips. Acknowledgement is due both of these men for their efficient help. During the progress of the field work the hearty co-operation of many producers of fluorspar in the district and of active prospectors, has been of the greatest service. Among those who have rendered especially material assistance are Mr. A. H. Reed, Mr. A. E. Shelby, Mr. Eugene Guess, Mr. B. E. Clement, Mr. C. W Haynes and Mr. Edgar Moore. Throughout the progress of the work Dr. W. R. Jillson, the State Geologist, has maintained his interest in the studies, and has co-operated in every way possible to further the investigation.

CROSSBEDDED HARDINSBURG SANDSTONE
It lies unconformably upon the Golconda Limestone.
Ohio River bluff at Weston. Photograph by A. C. Noe.

Previous Work. The only other systematic work on the geology of the quadrangle has been done by Ulrich[1] in the preparation of his report upon the lead, zinc and fluorspar deposits of western Kentucky. This work, prosecuted under the great handicap of a lack of adequate base maps, could only be of a rough reconnaissance character. It is quite evident from the geological maps published with that report, and from the description of the stratigraphy, that the author of it possessed a very imperfect knowledge of the stratigraphic succession in the region, and an inadequate knowledge of the structure. A generalized section of the stratigraphic succession in the so-called Birdsville formation of the Chester Series is presented[2], where twelve divisions are recognized. In later publications the same author has attempted to synchronize this generalized section with the stratigraphic succession as it has been worked out by the writer[3], but any such attempt is futile. Bed No. 1 of the Birdsville of Ulrich's section should be the Cypress sandstone, and in some localities such is the case, but in all of his writings he has confused the Cypress with the Tar Springs and other sandstones. In the original discussion of the Birdsville Bed No. 1, it is said to "occur over most of the area traversed by the Marion and Fredonia road."[4] This statement is literally true, but for about one-half the distance between Marion and Crayne, on this road, it is the Tar Springs which is exposed. It is also said that "east of Marion, along the road to the Tribune limestone outcrop, most of the exposures seem to be of the lower part" of Birdsville No. 1. As a matter of fact no Cypress sandstone is exposed along this road, but good outcrops of Hardinsburg, Tar Springs and Waltersburg are present. The sandstones in the railroad cuts east of Claxton, in the Princeton quadrangle, mentioned by Ulrich as Birdsville No. 1, are in fact Tar Springs.

Likewise in the interpretation of his Birdsville Bed No. 2, which should be the Golconda formation, Ulrich has shown that he is confused. A number of the localities specified by him are

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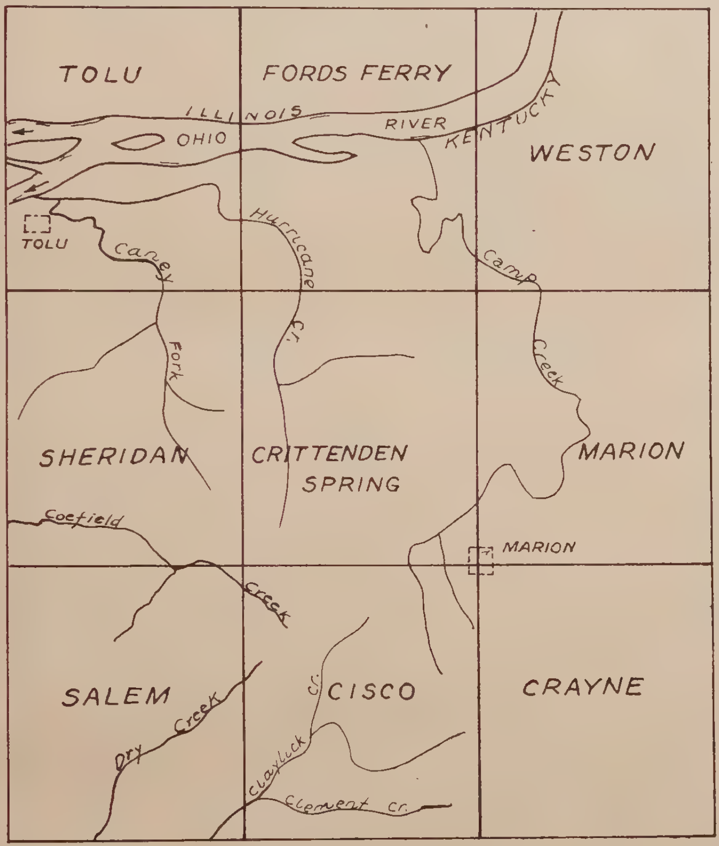
[1] U. S. Geol. Surv., Prof. Paper No. 36 (1905).

[2] Loc. cit., pp. 38 and 61.

[3] Ulrich, Miss Series in W. Ky., pp. 5-6, and 14 (1917).
Ulrich, Bull. Geol. Soc. Amer., vol. 33, p. 809 (1922).

[4] Ulrich, U. S. Geol. Surv., Prof. Paper No. 36, p. 62 (1905).



OUTLINE MAP
SHOWING
SUB-DIVISIONS
OF THE
CAVE IN ROCK QUADRANGLE

really Golconda, but the beds exposed in the railroad cut at Marion, determined by him to be the lower part of Birdsville No. 2, are really basal Menard limestone. The limestone at Carrsville, in the Golconda quadrangle, said by him to belong to this same horizon, is the Glen Dean limestone.

Ulrich's statement concerning his ten higher divisions of the Birdsville, shows that he knew little of the section. He says "these are much less frequently seen" and "most of them are unimportant, and the four at the top may be wanting entirely." When it is considered that above the Golconda limestone there are in the Cave in Rock quadrangle and elsewhere, two persistent sandstone formations, the Hardinsburg and Tar Springs, which are commonly 100 or more feet in thickness, and another one, the Palestine, which varies but little from 60 to 70 feet, and three persistent limestone formations from 50 to 100 feet thick, this statement certainly shows an inadequate knowledge of the section. In his latest attempt to synchronize the section as now known with his generalized section[1], Birdsville Bed No. 5 is made the equivalent of the Tar Springs sandstone. The original description of this bed is "Sandstone, usually absent......0-15 feet." The Tar Springs sandstone is really as important a formation as the Cypress, and the two were confused and all called Birdsville Bed No. 1 (Cypress) by Ulrich (not the Cypress of Ulrich).

The fossil lists published by Ulrich also show a great lack of information concerning the stratigraphic position of the faunas. For instance, in his lists of Glen Dean species[2], *Pentremites fohsi* is recorded in three faunas. When this species was originally named by Ulrich it was said to be from Birdsville No. 2 Golconda. The fact is it is one of the most characteristic index fossils of the basal beds of the Menard limestone. This horizon has nowhere been observed in good exposure, from Caldwell County, Kentucky, to Union County, Illinois, without furnishing examples of this fine species of Pentremite, and both of the localities mentioned as furnishing the type specimens are Menard limestone. The species has nowhere been observed by the writer in the Glen Dean limestone, and it is believed to be restricted to the basal Menard.

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[1] Ulrich, Bull. Geol. Soc. Amer., vol. 33, p. 809 (1922).
[2] Ulrich, Miss. Series in W. Ky., p. 226 (1917).

MINERAL DEPOSITS

It is not the purpose, in this report, to enter into a discussion of the mode of origin of the mineral deposits in this western Kentucky mining district, but there are some significent facts which have come out during the geologic mapping of the region, the proper appreciation of which may be of material assistance in further prospecting. It has long been recognized that the mineral deposits in the region are associated with the faults, and consequently a correct delineation of the fault structure is of the greatest importance to the practical miner, and it is believed that the accompanying map will be of much service. Up to the present time there has been no development of mines in the region except where evidences of mineralization are present at or close to the surface. In most places the first attraction for the prospector has been the finding of fragments of fluorspar washed out from the surface soil, but undoubtedly there are large bodies of mineral in the district which will only be detected through the application of scientific methods of prospecting.

It has been shown by Currier[1] that the fluorspar of the veins, in part at least, is a replacement of calcite or limestone. This replacement process has taken place more readily in connection with certain of the formations than with others, due doubtless to the chemical and physical characteristics of the limestones themselves. A survey of the really important mines of the district shows nearly all of them to be associated with the St. Louis or Ste. Genevieve limestones, and one or the other of these formations constitutes one and in some cases both walls of the veins which are being mined. This realtionship cannot be accidental, and must be due to the fact that the chemical and physical characteristics of these formations are more suitable for the carrying on of the replacement processes than are the other limestone formations, although some mineralization has taken place in connection with some of the other limestones. Because of this situation the surface indications of fluorspar, where successful prospecting has been accomplished, have been met with most commonly in localities where these formations have been exposed by erosion. However, at the time when these ore bodies were being accumulated this whole region was deeply buried beneath many hundreds of feet of sediments which have since been removed by erosion. Where the St. Louis limestone is now the surface rock, as much as 3,000 feet or more have been removed and since the St. Louis is the oldest formation exposed in this quadrangle it must follow that it is everywhere present at greater or less depths, dependent upon the magnitude of the faulting, and the Ste. Genevieve is everywhere present except where the St. Louis now constitutes the surface rock. There is no reason to believe that the accumulation of ore had been restricted to those locations where the St. Louis or Ste. Genevieve limestones are now exposed at the surface, and ore bodies may be expected at greater depths where these limestones are now completely buried. In searching for such more deeply buried deposits accurate knowledge must be available concerning the surface formations in order that the probable depth of the mineral deposits may be estimated. Prospecting for these deeper deposits will be a much more expensive undertaking than the prospecting of the past, but when the demand for fluorspar warrants the cost of such operation, there is little doubt but that an abundance of the material can be found.

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[1] Ill. State Geol. Surv., No. 41, p. 258 (1920).

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CHAPTER II

STRATIGRAPHIC GEOLOGY, IOWA SERIES.

INTRODUCTORY STATEMENT.

The stratigraphy of the Cave in Rock quadrangle is essentially the same as that exhibited in the Golconda quadrangle to the west and in the Princeton quadrangle to the southeast. Some of the formations persist through the three quadrangles with comparatively little change, but a number of them exhibit greater or less differences as they are traced laterally. Some of the Cave in Rock formations most resemble their equivalents in the Golconda, while others are more like those in the Princeton Quadrangle.

The St. Louis limestone is the oldest formation in the Cave in Rock quadrangle which is exposed at the surface and its position is well above the base of the Mississippian System. The youngest hard rock formation is the Caseyville which is a member of the Pottsville Group at the base of the Pennsylvanian System. In addition to these hard rock strata some unconsolidated sands of probable Cretaceous age are present locally within the quadrangle.

The formations which are buried beneath the St. Louis limestone are but little known in the quadrangle, and in the main the character of the unexposed strata must be inferred from our knowledge of the formations in adjacent regions. The only deep well within the limits of the quadrangle from which some information concerning the unexposed formations can be gained, was sunk in 1921 a little outside the eastern corporation boundary of Marion, near the Piney Fork road. The depth reached in this well is reported as 1,040 feet, and about 220 feet of sediments older than any of the exposed formations must have been penetrated. The reported log of this well is as follows:

LOG OF COOK WELL, ONE-THIRD MILE EAST OF
MARION POST OFFICE

	Thickness	Depth
Residum.		
Clay, red	7	7
Hardinsburg sandstone.		
Sandstone, white	45	52

LOG OF COOK WELL, ONE-THIRD MILE EAST OF MARION POST OFFICE—(Continued)

	Thickness	Depth
Golconda formation, Cypress sandstone and Paint Creek formation.		
Mud, red	10	62
Shale, blue	30	92
Limestone, dark	4	96
Shale, gray	73	169
Limestone, dark	2	171
Shale, gray	70	241
Bethel sandstone.		
Sand, white	47	288
Renault limestone.		
Shale, gray	20	308
Limestone, black	4	312
Limestone, hard, sandy	38	350
Shale, blue	2	352
Limestone, gray	15	367
Limestone, gray and shale mixed	30	397
Limestone, blue	2	399
Renault limestone or Lower Ohara limestone.		
Limestone, light brown	50	449
Rosiclare sandstone.		
Sand, dark	2	451
Fredonia limestone.		
Shale, blue	6	457
Limestone, gray	70	527
Limestone, dark	10	537
Limestone, gray	75	612
Limestone, gray, oolite specks	30	642
St. Louis limestone.		
Flint, hard	15	657
Limestone, gray	40	697
Flint, blue	30	727
Limestone, light brown	12	739
Limestone, gray	30	769
Chert, white and blue, very hard	33	802
Spergen limestone.		
Limestone, light brown	15	817
Limestone, gray (oolite)	40	857
Limestone, blue	20	877
Warsaw, passing down into Keokuk and possibly Burlington.		
Limestone, dark	8	885
Limestone, brown	40	925
Limestone, gray	8	933
Limestone, dark	25	958
Limestone or shale, dark	3	961
Sand	5	966
Limestone, dark	52	1018
Limestone, very dark	5	1023
Limestone, little lighter	10	1033
Limestone, still lighter	7	1040

There is something wrong with this log since no Cypress sandstone is recognizable as such, and no Paint Creek. On the other hand, the interval reported as having characteristics of the Golconda is excessive. The Cypress sandstone is well developed at the surface within a mile of the well, and it must exist in this section. It is possible that some portion of the beds recorded here as Golconda are really sandstone, for the entire interval of this Golconda is about equivalent to the normal combined thickness of the Paint Creek Cypress and Golconda. An earlier interpretation of this well log,[1] made before any detailed mapping had been done in the quadrangle, and when the sandstone in which it starts had not been identified from field studies, is incorrect and is superseded by the interpretation herewith.

A well near Princeton has been drilled to a depth of 2,017 feet[2] and penetrates the Middle Devonian limestone to a depth of 145 feet. In the other direction the strata down to the Middle Devonian limestone are exposed at the surface in Hicks dome in Hardin County, Illinois. The records in these two localities are not greatly different and it is reasonable to assume that in the Cave in Rock quadrangle, occupying an intermediate position geographically, the geological section is essentially similar. It is much less easy to predict the character of the sediments which underlie the Middle Devonian limestone. Lower Devonian sediments may or may not be present. The Silurian is probably present, represented by limestones, and a thick series of Ordovician beds may be safely assumed to be mostly limestones. Beneath the Ordovician a thousand feet, more or less, of Cambrian sediments are doubtless present, consisting of limestones, dolomites and sandstones. The entire thickness of sediments beneath the oldest formation exposed at the surface is probably 3,000 feet or more, perhaps as much as 4,000 feet, and beneath these in turn, would be expected the crystalline granites of pre-Cambrian age.

Throughout the entire area of the quadrangle considerable thicknesses of sediments have been removed by erosion. The youngest rocks of the quadrangle, Pottsville in age, have doubtless at one time spread over the entire area, and a considerable thickness of coal bearing strata of the Pennsylvanian, which are still present north and east of the Cave in Rock quadrangle, also must have extended over the entire district at one time. The maximum amount of erosion which has taken place where the St. Louis limestone is exposed at the surface, must have been at least 2,000 feet, and perhaps as much as 3,000 feet, and the minimum erosion where the Pottsville is now the surface rock, may have been 1,000 feet.

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[1] Ky. Geol. Surv., ser. 6, vol. 3, p. 108 (1922).
[2] Ky. Geol. Surv., ser. 6, vol. 10, p. 5 (1923).

The known geological column of the area and that which may be reasonably predicted for the strata now entirely hidden from view by younger formations, is shown in the following table:

Pennsylvanian				Pottsville sandstone, 200 feet or less.
Mississippian	Chester Series	Upper Chester		Kinkaid limestone, 0 to 125 feet.
				Degonia sandstone, ± 25 feet.
				Clore limestone and shale, ± 25 feet.
				Palestine sandstone, 60 to 75 feet.
				Menard limestone, 100 to 140 feet.
				Waltersburg sandstone, 20 to 50 feet.
				Vienna limestone, 30 feet, more or less.
				Tar Springs sandstone, 100 to 150 feet.
		Middle Chester		Glen Dean limestone, 60 feet.
				Hardinsburg sandstone, 100 to 140 feet.
				Golconda limestone, 80 to 100 feet.
				Cypress sandstone, 80 to 100 feet.
		Lower Chester		Paint Creek shale and limestone, 20 to 40 feet.
				Bethel sandsone, 40 to 50 feet.
				Renault limestone, 20 to 100 feet.
	Iowa Series	Meramec Group	Ste. Genevieve Limestone	Lower Ohara limestone 0 to 50 feet.
				Rosiclare sandstone, 2 to 20 feet.
				Fredonia limestone, 180 to 200 feet.
				St. Louis limestone, 350 feet.
				Warsaw limestone, 250 feet.
				Osage formation, 550 feet.
Devonian				Chattanooga shale, 400 feet.
				Devonian limestone, 350 feet.
Silurian, mainly limestone.				
Ordovician, mainly limestone, possibly with some sandstone near the top and bottom, and some shale in the higher part.				
Cambrian, sandstones and dolomitic limestones.				

DESCRIPTIONS OF FORMATIONS.

Iowa Series.

The entire Mississippian has been divided into two series, the Iowa Series below and the Chester Series above. The Iowa Series is made up almost entirely of limestone formations with subordinate thin beds of shale and sandstone. The most conspicuous of the sandstone beds and in many places the only one in the section is the Rosiclare sandstone, with a thickness up to 20 feet. The Chester Series in western Kentucky and southern Illinois is made up of a great succession of alternating sandstone and limestone-shale formations, some of the sandstones being thick and massive and forming great bluff exposures. The contrast between the lithologic characters of the two series is conspicuous.

The oldest formation of the Iowa Series which is exposed in the Cave in Rock quadrangle is the St. Louis limestone. The small area two miles southwest of Fords Ferry which has been mapped as Spergen limestone by Ulrich[1] is Fredonia in age, his incorrect determination of the oolitic limestone at that locality apparently being due to his misconception of the structure of the region. The St. Louis limestone with the overlying Ste. Genevieve limestone belong to the uppermost division of the Iowa Series, which has been named the Meramec Group. This name was first used by Ulrich[2] to include the Warsaw and St. Louis, the Ste. Genevieve being placed in the Chester Series by that author, but it has been shown conclusively that the Ste. Genevieve limestone, except locally, is separated from the St. Louis by no stratigraphic break, while it is everywhere separated by a distinct unconformity from the overlying Chester Series, and that its faunal relations are with the Iowa rather than with the Chester Series. Because of these facts the original limits of the Meramec Group have been expanded to include the Ste Genevieve.

ST. LOUIS LIMESTONE.

Name. The St. Louis limestone was named from the city of

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[1] U. S. Geol. Surv., Prof. Paper No. 36, pl. 11.

[2] U. S. Geol. Surv., Prof. Paper No. 24, table opposite p. 90 (1904); also U. S. Geol. Surv., Prof. Paper No. 36, p. 28 (1905).

St. Louis, Missouri, by Englemann in 1847[1], and although he had a wrong conception of its stratigraphic position, there is no doubt as to the formation which was described, and the name has been used for many years for one of the important stratigraphic units of the Mississippian.

Distribution. The St. Louis limestone is widely distributed in the Mississippi and Ohio valleys and in the southern Appalachians, being recognized from Iowa to Alabama. In the Cave in Rock quadrangle its surface exposures are restricted to the northwestern portion of the area. From Sheridan to the Ohio River this formation constitutes the surface rock almost throughout, and from Tolu to a point less than one mile west of Fords Ferry it is the formation underlying the unconsolidated surficial formations. The whole of the Tolu rectangle, in Kentucky, is underlain by St. Louis, and a large portion of the Sheridan rectangle. The western third of the Fords Ferry rectangle, in Kentucky, and between one and two square miles in the northwestern corner of the Crittenden Springs rectangle are also included in the St. Louis area.

Lithologic Characters. The lithologic character of the St. Louis limestone in the Cave in Rock quadrangle is like that in the neighboring areas. The district underlain by the formation is largely covered by the residual products of weathering, consisting of a mixture of red clay and chert fragments. In much of the area these residual materials have accumulated to a depth of twenty feet or more and few actual outcrops of the limestone are exposed. Even along the streams comparatively few rock outcrops are present, the valley floors being deeply buried beneath the characteristic chert fragments. Where the limestone is exposed it is from gray to dark bluish black to black in color, hard and compact in texture, and breaking with a more or less splintery fracture. No oolitic beds have been observed within the limits of the quadrangle although such beds do occur in the lower portion of the formation in the Princeton quadrangle. A surprisingly small amount of chert is present in the actual limestone exposures, a condition which suggests that the formation of the chert may be in part a surficial phenomenon connected with the processes of weathering.

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[1] Amer. Jour. Sci., 2nd ser., vol. 3, pp. 119-120 (1847).

Thickness. There are no outcrops in the quadrangle from which the thickness of the St. Louis limestone can be determined. Across the Ohio River in Illinois, where much better outcrops of the formation are exposed in the river bluffs, the St. Louis is as much as 350 feet thick. In the Cedar Hill well near Princeton[1] there is at least 300 feet of St. Louis, and perhaps as much as 400 feet, and in the well drilled near Farmersville[2] 335 feet of the limestone was penetrated, but the base of the formation was not reached. It is reasonable to conclude that the thickness in the Cave in Rock quadrangle is similar to that in adjacent areas, and it will be safe to consider it as being 350 to 400 feet.

Stratigraphic Relations. There is no reason to conclude that the stratigraphic relations of the St. Louis limestone are any different in the Cave in Rock quadrangle than elsewhere in the Ohio Valley, although the outcrops are not such as to exhibit the contacts with underlying and overlying limestones. It is well established that no stratigraphic break exists either beneath or above the St. Louis, consequently both the Spergen or Salem, and the Ste. Genevieve boundaries are more or less arbitrary. The formation is not limited by sharply defined boundaries so that even if the best of exposures were present it would be difficult to establish the exact position of the transitions into the underlying and overlying formations. Ulrich insists that the local unconformity between the St. Louis and the overlying Ste. Genevieve, which is exhibited in some localities in Ste. Genevieve County, Missouri, persists throughout the extent of the two formations, but there is no basis anywhere in the Ohio Valley for such a conclusion, in the actual field relations of the two formations. In actual field practice, wherever examples of the coral species *Lithostrotion canadensis* or *Lithostrotion proliferum* are observed, the beds are referred to the St. Louis, and where oolitic limestones become a notable characteristic of the formations the beds are referred to the Ste. Genevieve, although it must be kept in mind that oolitic beds may be present in the lower portion of the St. Louis. The lines upon the geological map separating these two formations are drawn with altogether inadequate knowledge. Where oolitic cherts have been observed it has been assumed that the Ste. Genevieve limestone is present, but such oolitic cherts, originating in the Ste. Genevieve limestone, may well occur as residuum in association with St. Louis cherts where the St. Louis is actually the underlying rock. Under these conditions the boundary lines on the map between the St. Louis and Ste. Genevieve are of only approximate value.

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[1] Ky. Geol. Surv., series 6, vol. 10, p. 5 (1923).
[2] Ky. Geol. Surv., series 6, vol. 10, p. 102 (1923).

Paleontology. No attempt has been made to collect the fossils of the St. Louis limestone in this quadrangle. The limestone as exposed rarely exhibits any other fossils than the two species of *Lithostrotion* and in places these, especially *L. prolifcrum,* occur in great numbers. There are places where both the limestone itself and the residuum are literally crowded with fragments of this coral. The other species, L. *canadensis,* does not occur in such great numbers, and commonly it is an indication of a somewhat higher horizon in the formation.

Correlation. No special questions are involved in the correlation of the St. Louis limestone. It is a widely spread formation, from Iowa to Alabama, rather uniform in its lithologic characters throughout, and everywhere containing specimens of the two species of *Lithostrotion* which are most excellent index fossils.

STE. GENEVIEVE LIMESTONE

Name. The Ste. Genevieve limestone derives its name from Ste. Genevieve, Missouri, from which locality the formation was named in 1859 by Shumard[1]. Ulrich was the first to recognize the presence of beds in western Kentucky equivalent with those at Ste. Genevieve. He first called the formation the Princeton limestone,[2] but later,[3] on recognizing its equivalence with Shumard's formation, he dropped this name and substituted Ste. Genevieve.

Distribution. In its general distribution the Ste. Genevieve limestone stretches from Iowa to Alabama, being present throughout nearly the same area as the St. Louis.

In the Cave in Rock quadrangle the Ste. Genevieve limestone occupies a considerable area in the Salem rectangle in the southwestern portion of the area, and the Salem-Marion highway traverses this formation from Salem to the foot of Moore's Hill, about four miles from Marion. Just east of Salem this area is more than two and one-half miles wide, but northeast from Salem it narrows to a belt little more than a mile in width. North from Moore's Hill in this same belt the formation continues for about four miles to the Memphis Mine road running northwest from Marion, but in this direction the northeasterly dip of the strata brings in younger formations in the hills and the Ste. Genevieve becomes less continuous in outcrop until it disappears beneath the younger formations northeast of the road mentioned. One of the best exhibitions of the formation is along the Crittenden Spring road from a point about three miles from Marion to the spring.

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[1] Trans. St. Louis Acad. Sci., vol. 1, p. 406 (1859).

[2] Crittenden Press, Dec. 1890; Bull. U. S. Geol. Surv., No. 213, p. 207 (1903).

[3] U. S. Geol. Surv., Prof. Paper No. 36, p. 39 (1905).

A second area of considerable size where the Ste. Genevieve limestone is the surface formation, is in the southern part of the Cisco rectangle, six miles southwest of Marion, where it underlies the View Valley. This area is subtriangular in outline, the sides of the triangle being between three and four miles in extent.

Aside from these larger areas the Ste. Genevieve limestone is probably present in two small contiguous areas in the western part of the Sheridan rectangle, overlying the St. Louis limestone. The presence of the formation is not established by actual outcrop in these areas, but oolitic cherts are present in the residuum, and the exact position of the boundary between the St. Louis and the Ste. Genevieve is not determinable. Within the more faulted portions of the quadrangle a number of smaller areas of the Ste. Genevieve are present in the Sheridan, Crittenden Spring and Fords Ferry rectangles. In the Sheridan rectangle the formation outcrops in the proximity of the Holly Mines. In the Crittenden Spring rectangle it is in the neighborhood of the Beard Mines, where it comprises the whole or a part of four smaller fault blocks. In the Fords Ferry rectangle it is at and north of Dunn Springs, apparently in two distinct fault blocks. It is probably this last area which was mapped as "Spergen limestone" by Ulrich,[1] doubtless on the evidence of the oolitic limestones alone.

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[1] U. S. Geol. Surv., Prof. Paper, No. 36, plate 11 (1905).

Subdivisions of the Ste. Genevieve. The same subdivisions of the Ste. Genevieve limestone are recognized in the Cave in Rock quadrangle as elsewhere in the Ohio Valley. The greater portion of the formation is the Fredonia limestone member. The Rosiclare sandstone member is uniformly present wherever its proper horizon comes to the surface. The Lower Ohara member is also recognizable but it is less well developed than in some other regions. In places, especially in the district about the Memphis Mines, this higher member is absent entirely, and the Renault limestone rests directly upon the Rosiclare sandstone. Elsewhere it seems to be present, but it is everywhere more or less obscured by talus accumulations.

Lithologic Characters. The lithologic character of the Ste. Genevieve limestone is in no way different in the Cave in Rock quadrangle from the exposures in the adjacent areas. The Fredonia limestone member is in the main an oolitic limestone, much of it light colored or nearly white. Interbedded with the oolitic strata there are other light colored limestones which are more or less crystalline or somewhat dense in texture. The higher beds are lighter in color than the lower, and likewise the oolitic texture is more pronounced in the higher part of the formation. In the lower half of the formation the oolitic strata become less and less conspicuous, more beds of dense texture are present, and somewhat darker colors prevail, and it merges without stratigraphic interruption into the underlying St. Louis limestone.

The residual material from these limestones consists of red clay with included cherts. In places the cherts are fully as abundant as those in the similar residuum from the St. Louis limestone, but there are localities, perhaps representing certain horizons in the limestone, where the deep red Fredonia residuum is essentially without cherts.

The Rosiclare sandstone member is like the same bed elsewhere. As commonly exposed it is a porous, reddish brown sandstone which occurs in more or less tumbled masses due to the solution of the limestone beneath. Where encountered below the zone of weathering the bed is more calcareous and lighter in color.

The Lower Ohara member is similar in lithologic character to the higher portion of the Fredonia member. In fact, in isolated outcrop it is not possible to distinguish the two limestones.

Thickness. The greatest actually exposed thickness of the Ste. Genevieve in the Cave in Rock quadrangle is in the proximity of Crittenden Springs, where about 120 feet of the higher portion of the formation is exhibited. How much greater than this the thickness actually is must be determined indirectly. The only deep well record available in the quadrangle is in the eastern outskirts of Marion, near the Piney Fork road. In this well 243 feet may be referred safely to the Ste. Genevieve, at depths from 399 to 642 feet. Of this thickness 191 feet are Fredonia, 2 feet Rosiclare sandstone, and 50 feet Lower Ohara. This thickness agrees well with estimates in the adjoining territory. The estimated thickness in the Golconda quadrangle is 250 feet. In the Princeton quadrangle the thickness cannot be less than 200 feet nor greater than 300 feet, so that 250 is a fair estimate. A similar thickness is also recognized in Hardin County, Illinois. The Fredonia limestone is the least variable member of the formation, it being about 200 feet. The Rosiclare sandstone probably nowhere exceeds 20 feet, and in places is as thin as 2 feet. The Lower Ohara exhibits the greatest variation in thickness because of the pre-Chester erosion. In places it is as much as 50 feet, and elsewhere it may be lacking altogether, as in the Memphis mine area, where the Renault rests upon the Rosiclare sandstone.

Stratigraphic Relations. The St. Louis limestone passes into the Fredonia with no interruption, the exact line separating the two formations in this district being quite arbitrary, as has already been pointed out.

At the summit, the Ste. Genevieve everywhere in the district, lies unconformably beneath the overlying Chester formations. The claim has been made repeatedly by Ulrich that this unconformity in the midst of his so-called Ohara member of the Ste. Genevieve is of no consequence, and he includes the Renault limestone of this report in his Ste. Genevieve and carries the base of the Chester Series to the top of the St. Louis limestone, where in reality there is no known stratigraphic break whatever except locally in southeastern Missouri on the flank of the positive Ozark area. Ulrich has claimed further, that the most characteristic Fredonia fossils pass upward into the "Upper Ohara" (Renault). The Levias locality which has been repeatedly mentioned in the discussion of this point is situated in the Cave in Rock quadrangle. Mr. Chas. Butts of the United States Geological Survey, and the writer visited this locality together in the summer of 1918, and both of us were satisfied at that time that Ulrich was in error. At a later date (1921) Butts again visited the same locality in company with Ulrich, and this time he agreed completely with Ulrich's interpretation.[1] At the time of our 1918 visit the following description of the locality from which the fossils in dispute were collected was furnished by Ulrich: "Locality for *P. huntsvillae* in the Ohara. One-half mile southeast of Levias which is 5 or 6 miles west-southwest of Marion. Locality a short distance west of the Manley or Miller shaft and between shaft and hill with Aux Vases sandstone." When Butts and the writer visited this locality we recognized the same stratigraphic succession as was known elsewhere, viz., Fredonia limestone, Rosiclare sandstone, Ohara limestone (of Ulrich), and Bethel sandstone (Cypress and later Aux Vases of Ulrich). We examined first the hillside to the east where beds beneath the Bethel sandstone are well exhibited, and found the same faunal assemblage (Renault) which everywhere occurs in those beds, and no indication of the characteristic Ste. Genevieve limestone forms which Ulrich had reported. We then turned to the memorandum which Ulrich had supplied regarding the locality, and found that we were directed to the hill side *west* of the mine shaft designated. We went there and found the Fredonia fauna and the hill capped with Rosiclare instead of Bethel sandstone. In Ulrich's description of his visit to this locality with Butts in 1921[2] it is stated that they searched the hill side *east* of the mine shafts instead of west, which were our directions in 1918, and soon "found the shaly bed from which the fossils in question were collected in 1903". None of the characteristic species of the Ste. Genevieve were found, however, in the 1921 visit. The species secured at this time are indicated in the list given,[3] and of these only the form listed as *Platycrinus* cf. *penicillus* need be considered, all of the others being good Renault species. Even Ulrich, in this list, only compares this species of *Platycrinus*. There are present in the Renault limestone not uncommonly, elliptical brachial plates of a crinoid, evidently a member of the family Poteriocrinidae, which simulate the stem plates of Platycrinus. They possess a similar longitudinal articulating ridge and are about equal in size to some of the stem plates of *Platycrinus penicillus*. On close examination, however, these plates are seen to be not quite symmetrical, and they never possess the marginal spines of the *Platycrinus*. It is believed to be plates of this sort which Ulrich observed in his 1921 visit to the Levias locality and compared with *P. penicillus* in his faunal list. At this time he apparently found nothing but perfectly good Renault species. The earlier collection (1903) which has been exhibited by him at times, does contain characteristic Fredonia forms and must have been collected *west* of the mine shafts, as indicated in his description of the locality in 1918. In his latest paper he states that it would be "not only improbable but almost impossible" for him to mistake the Rosiclare sandstone for the Bethel, but that he did confuse these two formations is proven by a glance at his geological map of this area.[1] The mine shafts which have been mentioned at this locality are those marked 78, 79, 80, 81 and 82, a little southeast of Levias, and the two sandstone covered hills in question, one northeast and the other southwest of the mineral vein, are both indicated upon his map as Cypress sandstone (Bethel). The actual facts are that the hill to the northeast is capped by Bethel sandstone, and the one to the southwest by the Rosiclare. Elsewhere on the same map there are areas of the Rosiclare sandstone which are given the Cypress symbol, proving not only that it was possible for him to mistake the Bethel and Rosiclare sandstones, but that he actually did make this error repeatedly.

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[1] Bull. Geol. Soc. Amer., vol. 33, p. 817.
[2] Loc. Cit., p. 816.
[3] Loc. Cit., p. 817.

As to the presence of *Amplexus geniculatus*, recorded by Ulrich in this supposed Renault (Upper Ohara) collection of 1903 containing Fredonia species, it may be said that the writer has collected in the Fredonia limestone on occasions, fragmentary corals, cylindrical in form, and comparable in size with that species, which on superficial examination might be so identified, but more careful study shows them to be something different. Ulrich may have had specimens of this sort in his original collection.

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[1] U. S. Geol. Surv., Prof. Paper No. 36, plate 8.

None of the evidence which Ulrich has presented in his recent papers is sufficient to establish his contention that the Ste. Genevieve should be included in the Chester Series. The facts remain that no stratigraphic break exists between the St. Louis and Ste. Genevieve limestones, except locally, while there is an important and wide-spread unconformity between the Ste. Genevieve and the Renault (Upper Ohara of Ulrich), and furthermore, the most diligent search has failed to establish the presence of characteristic Ste. Genevieve species in the "Upper Ohara" in the association of species which Ulrich claims to have found.

Paleontology. The limestones of the Ste. Genevieve are everywhere filled with fragments of organic remains, but localities from which good fossils can be collected in abundance are not common. The most important index fossil of the formation is the crinoid *Platycrinus penicillus*, whose characteristic stem plates, elliptical in outline with a row of marginal spines, may be found on weathered surfaces in most exposures where sufficient search is made, and in some places they are really abundant. Less frequently the characteristic bases of the same crinoid are met with which may be easily recognized from the three ridges which radiate from the margin of the stem facet. This crinoid is also present in the St. Louis limestone in places, but it has never been found to be so common in that formation as in the Ste. Genevieve. In practice, wherever these *Platycrinus* stem plates are found in abundance the beds may be considered safely as being Ste. Genevieve limestone. For more complete lists of the Ste. Genevieve limestone fossils reference may be made to the report on the Princeton quadrangle.[1]

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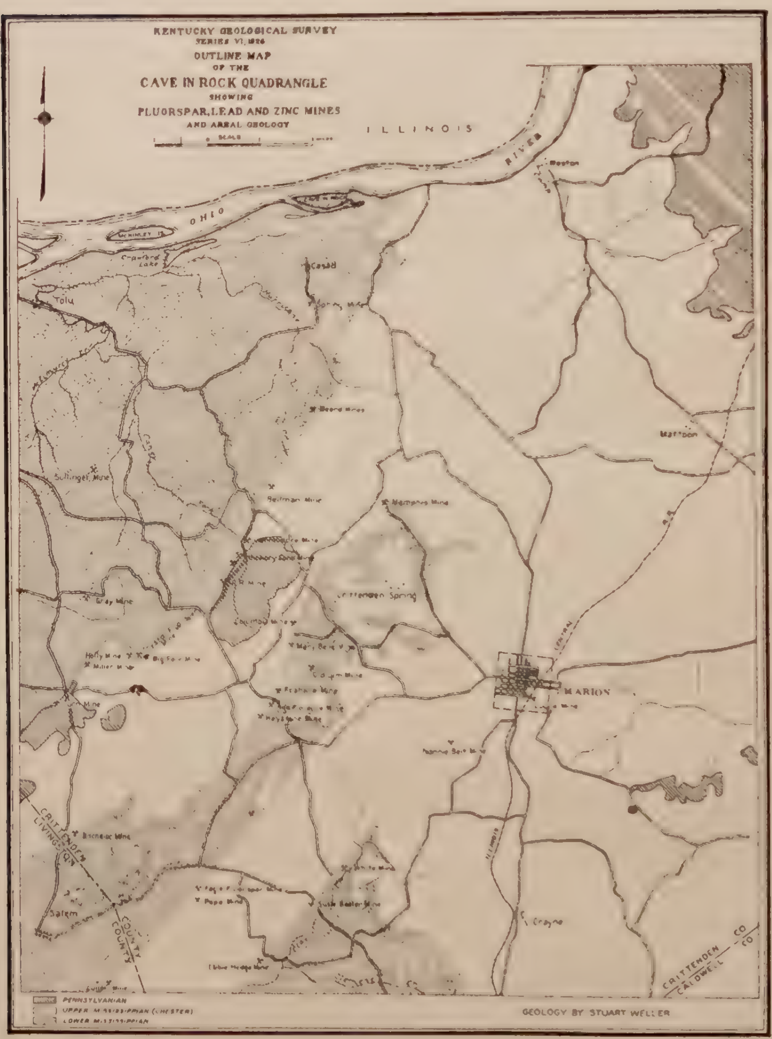
[1] Ky. Geol. Surv., ser. 6, vol. 10, pp. 29-30 (1923).



AREAL GEOLOGY OF THE CAVE IN ROCK QUADRANGLE.

CHAPTER III

STRATIGRAPHIC GEOLOGY, CHESTER SERIES.

The greater portion of the Cave in Rock quadrangle in underlain by the formations of the Chester Series, the entire Chester section, as exhibited in western Kentucky being well shown. Because of the extensive faulting of the region the several formations are much scattered in their distribution, a condition which has added greatly to the difficulty in mapping the formational boundaries. The characteristics of the formations agree in general with those of the exposures in adjacent areas, although some of the formations exhibit a notable change in lithologic character in their lateral distribution.

RENAULT LIMESTONE.

Name. The Renault limestone is the basal formation of the Chester Series in the Cave in Rock quadrangle and in the adjoining portion of the Ohio Valley region. It was originally named from the typical exposures in Monroe County, Illinois, where it differs somewhat in lithologic character from the expression in western Kentucky, but the detailed mapping of the Chester Series has now progressed so far that the formation has been traced entirely across southern Illinois, connecting the Mississippi River sections with those of the Ohio Valley.

Distribution. The Renault commonly occurs wherever the underlying Ste. Genevieve limestone is exposed. The formation in most localities occurs, with the "Lower Ohara" member of the Ste. Genevieve, occupying more or less steeply sloping hillsides between the Rosiclare and Bethel sandstones. In many places it is more or less completely talus covered, but not infrequently there are glade-like exposures, especially upon southern hill slopes. In the Cave in Rock quadrangle the Renault is well exhibited in the Salem rectangle about both of the Eberle Knobs one mile northeast of Salem, and also in the slopes of the Kirk Knobs and their ridge-like extensions to the north. Across the valley north of the extremities of the Kirk Knobs, the Renault is present in a belt extending for a mile or more between the Commodore and Levias faults. The most extensive outcrops of the formation are present in the belt bounded by the Levias, Crittenden Springs and Klondike faults on the northwest, and the Moore's Hill fault on the southeast. In this belt the Renault is present in the hill slopes completely surrounding the ridge-like hill about one and one-fourth miles long, about three-fourths of a mile east of Levias. It is also present in a similar situation about the two elongated hills north of Moore's Hill, between the Sheridan road and the Marion-Salem road, and again in the slopes of the subtriangular hill lying a half mile northeast of the last mentioned hills. All three of the hillside exposures last mentioned are in the northwestern corner of the Cisco rectangle, and continue across the borders of this rectangle into the Salem rectangle to the west and into the Crittenden Spring rectangle to the north. Still farther northeast in this same belt, the most extended continuous outcrop of the formation in the district exists in the southern half of the Crittenden Springs rectangle. From the Marion-Crittenden Springs road on the southwest to the hill slopes northeast of the Marion-Memphis Mine road, the Renault limestone is exposed in a sinuous belt following the rather steep hill slopes beneath the overlying Bethel sandstone which caps the hills.

Another extensive area of outcrop of the Renault is in the Cisco rectangle where the formation is exposed along a narrow belt in the steep, westerly facing hillslopes limiting the View valley on the east and in the bluffs of Preacher Creek. In this same region the formation is exposed in the heads of several of the valleys tributary to Preacher Creek, south of fault No. 91.

The remaining exposures of the Renault limestone in the Cave in Rock quadrangle are of small extent. There are two small areas of outcrop west of the Holly Mines, a little over a mile southwest of Sheridan, in the southern part of the Sheridan rectangle, and other outcrops exist about a mile northeast of the Beard Mines, near the southern edge of the Fords Ferry rectangle. The last outcrops to be mentioned are present in the Fords Ferry rectangle, in the steep hill slope around the southern end of the high hill one and one-half miles southwest of Fords Ferry, and in the slope to the south and to the west from the sandstone capped hill near the wedge-like extremity of the fault block lying between the Commodore fault and fault No. 5.

Lithologic Characters. The Renault formation is for the most part gray to dark colored limestone of variable texture, some beds being more or less crystalline, others being dense and compact. The individual beds of limestone, up to several feet in thickness, are separated by thin shaly partings, and in the lower portion of the formation there is one more persistent shaly member, fifteen feet, more or less, in thickness, which is likely to be exposed in glade-like outcrops upon the southern slopes of the hills. Such glade exposures are the most prolific sources for the fossils of the formation, and in some localities great numbers of beautifully preserved shells may be gathered in such situations. This shaly horizon is persistent to the north and west in Livingston County, Kentucky, and in Hardin County, Illinois, and comprises what has been designated as the Shetlerville member of the formation. This member is not so well developed to the southeast, in the Princeton quadrangle.

The basal conglomerate layer of the Renault has been observed at a number of localities in the quadrangle, one of the best exposures being in "The Sinks" northeast of the Memphis Mines. Much of the Renault outcrop is more or less obscured by talus accumulations so that the basal contact of the formation where the conglomerate occurs, is not generally exposed, but in most localities, from the Princeton quadrangle to Hardin County, Illinois, where this contact has been observed, the conglomerate is present. It is a thin bed, in most places about a foot in thickness, and is associated with the unconformity between the Chester Series and the underlying Ste. Genevieve.

Thickness. The thickness of the Renault in the Cave in Rock quadrangle is similar to that which has been observed elsewhere, in most places being about seventy-five feet, although locally it may attain a thickness of as much as one hundred feet. In the region east and northeast of Crittenden Springs the formation is notably reduced in thickness. At one point a little less than one and one-half miles northeast of the springs there being a possible interval of only about twenty feet for the formation, and at a number of points in the same general region the thickness cannot exceed forty feet.

Stratigraphic Relations. As has been pointed out elsewhere, evidence of unconformity is everywhere present in the Ohio Valley, at the base of the Renault. In most localities where the basal contact can be seen there is evidence of the basal conglomerate. The pebbles in this conglomerate are all of limestone and the matrix is also limestone. The pebbles are angular in outline and vary in size from less than half an inch to one or two inches. The varying thickness of the "Lower Ohara" member of the Ste. Genevieve limestone is due to the pre-Renault erosion of the existing land surface. Locally this erosion was sufficient to remove the "Lower Ohara" in its entirety and to permit the Renault to rest upon the Rosiclare sandstone, this being the situation in the vicinity of the Memphis Mine between three and four miles northwest of Marion. A distinct faunal change is exhibited in passing from the Ste. Genevieve into the Renault limestone, the characteristic Ste. Genevieve species disappear at this point and the Chester forms make their appearance. These features, along with the notable changes in geographic pattern of the Mississippian seas, make this the most important stratigraphic break within the Mississippian, being the line of separation between the Iowa and the Chester Series.

At its upper limit the Renault probably lies unconformably beneath the Bethel sandstone. The actual contact between these two formations is only rarely exposed, but certain evidences of unconformity are exhibited in the Ohio River bluffs east of Cave in Rock on the Illinois side of the river, in the Cave in Rock quadrangle.[1] Similar conditions would doubtless be exhibited in Kentucky if the actual contact between the two formations could be observed. Further evidence of the unconformity above the Renault is furnished by the varying thickness of the formation, this condition being due to the erosion of the limestone before the deposition of the Bethel sandstone.

Paleontology. A number of excellent collections of fossils from the lower, shaly, Shetlerville member of the Renault limestone have been secured in the Cave in Rock quadrangle. A combined list of this fauna is given in the following table, the checks in the several columns indicating the composition of the fauna at the several localities. Column 1 is at the Lemon quarry three miles west of Marion, 2 is a glade near Bethel School, 3 is a glade opposite Moore's Hill.

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[1] Ill. State Geol. Surv., Bull. No. 41, p. 145 (1920).

FOSSILS FROM THE SHETLERVILLE MEMBER OF THE RENAULT FORMATION COLLECTED IN CRITTENDEN COUNTY, KENTUCKY

FOSSILS	1	2	3
Triplophyllum spinulosum (M.-E. and H.)	X	X	X
Amplexus geniculatus Worthen	X	X	X
Spirorbis sp	X	X	X
Eupachycrinus sp	X	..	..
Globocrinus unionensis (Worthen)	..	..	X
Talarocrinus buttsi Ulrich	X	..	..
Crinoid stems and plates	X	X	X
Pentremites princetonensis Ulrich	..	X	X
Pentremites pulchellus Ulrich	..	..	X
Mesoblastus glaber (M. and W.)	..	X	..
Ascodictyon sp	..	..	X
Hederella sp	X	..	..
Fistulipora excelens Ulrich	X	X	X
Eridopora punctifera Ulrich	X	..	X
Stenopora tuberculata (Prout)	X	X	X
Stenopora sp	X	..	..
Fenestella cestriensis Ulrich	X	X	X
Fenestella elevatipora Ulrich	X	..	X
Fenestella serratula Ulrich	X	X	X
Fenestella tenax Ulrich	X	..	X
Archimedes sp	X	..	..
Polypora cestriensis Ulrich	..	..	X
Polypora spinulifera Ulrich	X	..	..
Thamniscus ramulosus Ulrich	..	..	X
Septopora subquadrans Ulrich	X	X	X
Rhombopora sp	..	..	X
Streblotrypa nicklesi Ulrich	..	..	X
Cystodictya labiosa n. sp	X	X	X
Glyptopora punctipora Ulrich	X	X	X
Crania chesterensis M. and G.	X	..	X
Orthotetes kaskaskiensis (McChesney)	X	X	X
Productus ovatus Hall	X	X	X
Diaphragmus elegans (N. and P.)	X	X	X
Girtyella indianensis (Girty)	X	X	X
Girtyella brevilobata (Swallow)	..	X	..
Dielasma illinoisensis Weller	X	X	X
Spiriferina transversa (McChesney)	X	X	X
Spiriferina subspinosa Weller	X	X	X
Cyrtina ?? sp	X	..	..
Spirifer breckenridgensis Weller	X	X	X
Spirifer leidyi N. and P.	X	..	X
Spirifer increbenscens Hall var	X	X	X
Reticularia setigera (Hall)	X	X	X
Eumetria vera (Hall)	X	X	X
Eumetria costata (Hall)	..	X	..
Cliothyridina sublamellosa (Hall)	X	X	X
Composita trinuclea (Hall)	X	X	X
Allorisma sp	..	X	..

FOSSILS FROM THE SHETLERVILLE MEMBER OF THE RENAULT FORMATION COLLECTED IN CRITTENDEN COUNTY, KENTUCKY —Concluded.

FOSSILS	1	2	3
Bellerophon sp.	..	..	X
Pleurotomaria ? sp.	..	..	X
Pleurotomaria ? sp.	X	..	..
Orthonychia cf. chesterensis M. and W.	..	X	..
Conularia sp.	X	..	..
Orthoceras sp.	..	..	X
Phillipsia sp.	..	X	X

Correlation. The correlation of the Renault limestone in the Ohio Valley has been fully discussed elsewhere.[1] The formation has been included in the Ohara member of the Ste. Genevieve limestone by Ulrich, but the evidence for excluding the "Upper Ohara" from the Ste. Genevieve continues to pile up with each successive field season, and at the present time the formation has been actually followed in detailed mapping from Princeton, Kentucky, across western Kentucky and southern Illinois to the Mississippi River sections in Illinois, and both the faunal and stratigraphic studies serve to establish the identity of these beds in Kentucky with the typical Renault of Monroe County, Illinois.

BETHEL SANDSTONE

Name. The Bethel sandstone was named by Butts from a locality in the Cave in Rock quadrangle near Bethel School,[2] three and one-half miles west of Marion on the Crittenden Springs road. This is the formation which Ulrich erroneously called Cypress in his report[3] but in many places he failed to differentiate it from the true Cypress, the Hardinsburg, and the Tar Springs sandstones. Butt's name for the formation is an unfortunate choice because in the type locality the line of demarkation between the Bethel and Cypress sandstones is not exposed. In the bluff back of Bethel School no actual exposure of the Bethel sandstone can be seen, the massive sandstone ledges which were believed to be a part of the formation by Butts being the lower portion of the Cypress sandstone. In this bluff the Bethel and the overlying Paint Creek are both comparatively thin, and are wholly covered by the talus from the massive Cypress sandstone which caps the hill, although a thin shale bed or zone of thinly bedded sandstone is undoubtedly present at the Paint Creek horizon, since it has been observed both a few miles north, a few miles south, and a few miles west of this locality.

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[1] Ill. State Geol. Surv., Bull. No. 41, pp. 150-159 (1920).
Ky. Geol. Surv., ser. 6, vol. 4, p. 34 (1921).
Ky. Geol. Surv., ser. 6, vol. 10, p. 38 (1923).

[2] This School is named Crittenden Spring School on the map.

[3] U. S. Geol. Surv., Prof. Paper No. 36, p. 53.

Distribution. In every locality in the Cave in Rock quadrangle where the Renault limestone is known, it is overlain by the Bethel sandstone, so that the description of the distribution of the Renault will apply as well to the Bethel. The Bethel is a hill capping and bluff forming sandstone which rises above the more or less talus covered slopes underlain by the Renault limestone. On the Eberly and Kirk Knobs, and on the ridge-like hills east and northeast of Levias, the Bethel comprises the whole of the sandstone capping, but elsewhere above the Renault, it is only the lower portion of the sandstone, the higher portion being the Cypress.

Lithologic Characters. The Bethel is a moderately coarse sandstone, brown or reddish brown upon weathered surfaces, and commonly lighter in color upon freshly broken surfaces. The texture is mostly uniform, although in a few places some small white pebbles have been observed in the formation. The beds are massive and where not talus covered they rise in more or less vertical bluffs.

Thickness. Throughout much of the Cave in Rock quadrangle it is not possible to determine the thickness of the Bethel sandstone because the interval between it and the Cypress is completely hidden by talus. The only locality where the thickness has been established with any degree of certainty is along Preacher Creek a little less than one and one-half miles northeast of View, about one-fourth of a mile below where the Marion road crosses the creek. In the east bank of the creek at this point the contact of the Bethel upon the Renault limestone is clearly shown. The sandstone rises vertically for about twenty-five feet above which there is a sloping, terrace-like interruption of the hill slope with the massive cliffs of Cypress sandstone above. On following this terrace around the hillside to the southeast it is seen to represent the Paint

Creek outcrop. It is unlikely that the Bethel sandstone is exhibited in its entirety in the exposed cliff at this point, and it may extend several feet higher, but at the most the thickness cannot exceed 40 feet, which is about the maximum thickness of the formation in the Princeton quadrangle. In the northern portion of the quadrangle the Paint Creek shale is exposed but not in the same section with the top of the Renault limestone, but the position of the Paint Creek is such as to permit as much as 40 feet of Bethel sandstone and perhaps more.

In the log of the well drilled in 1921 in the eastern part of Marion,[1] and incorrectly interpreted by the writer before a sufficient knowledge of the surface outcrops in the vicinity was available, it is not certain what thickness should be assigned to the Bethel. It is now known that the sandstone at the surface where the well was drilled is Hardinsburg, and that the series of shales and limestone beneath this sandstone is the Golconda, the total thickness of the beds referable to the Golconda being excessive. The combined thickness of the Cypress, Paint Creek and Bethel formations is deficient, there being only 47 feet, between the depth 241 and 288. It is possible that the 47 feet is all Bethel and that in the overlying interval of 70 feet referred to as gray shale, some error has crept in. This 70 feet is where the Cypress and Paint Creek ought to be, and the Cypress is well developed as a sandstone at the surface less than a mile from the well. Between the Cypress and Bethel there should be a thin interval of Paint Creek shale. If the suggested error has crept into this record, the thickness of the Golconda becomes more nearly what should be expected, and the Cypress and Bethel approach somewhat near the normal development for the region.

In all probability the usual thickness of the Bethel in the Cave in Rock quadrangle is about 40 feet, although in the Golconda quadrangle to the west the thickness is greater, being as much as 100 feet in one section, but being more commonly about 60 feet. The 100 feet assigned to the formation by Butts[2] at the type locality includes not only the Bethel, but the overlying Paint Creek and Cypress as well.

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[1] Ky. Geol. Surv., ser. 6, vol. 3, p. 108 (1922).
[2] Ky. Geol. Surv., Miss. Form. W. Ky., p. 63.

Stratigraphic Relations. The Bethel sandstone rests unconformably upon the Renault wherever the contact between the two formations has been observed. The best locality to observe this contact in the Cave in Rock quadrangle is in the east bank of Preacher Creek about one and one-half miles northeast of View. Nothing which has been seen in the Cave in Rock quadrangle adds to our knowledge of the stratigraphic relations of the Bethel with the overlying Paint Creek formation. There is some evidence of unconformity at this horizon in adjoining areas, but it is hardly conclusive.[1]

Paleontology. Like the sandstone formations of the Chester Series generally, the Bethel is essentially without fossils.

PAINT CREEK FORMATION.

Name. The Paint Creek formation derives its name from a locality in Monroe County, Illinois, and from the type locality it has been traced and mapped in detail to Caldwell County, Kentucky, where it includes certain strata to which Ulrich applied the name Tribune limestone. In their later writings both Ulrich and Butts have used the name Gasper in place of the older name Tribune, but the proposal of this name was entirely unnecessary because of the exact equivalence of the Caldwell County Tribune with the Paint Creek formation of Weller. In another place Butts has used the name Ridenhower shale[2] for equivalent beds, a name which was used for a local manifestation of the formation in southern Johnson County, Illinois, during one of the Chester field conferences, but which was never suggested with the idea of its being adopted as a true formation name.

Distribution. In the Cave in Rock quadrangle good exposures of the Paint Creek formation have been observed in only three localities. The first of these is in the southern portion of the Cisco rectangle along Preacher Creek where the Marion-Chapel Hill-View road crosses that stream and follows its valley for a short distance, about a mile and one-half northeast of View. In these exposures the shale, impure limestone and thinly and irregularly bedded sandstones are well exposed. A second locality near the western boundary of the Marion rectangle is on Crooked Creek, a little less than two miles north of the Court House in Marion. The outcrop may be seen in the roadside just north of the creek, at the crossing a little less than one-half mile above the covered bridge on the Fords Ferry road. At this place several feet of impure limestone and thinly bedded sandstone are exposed, but neither the upper nor the lower limits of the formation can be certainly established. The third locality is in the southeastern portion of the Fords Ferry rectangle along Crooked Creek, where both shale and limestone can be seen. The formation is probably present in the intervening areas wherever the Bethel and Cypress sandstones are exposed, but the talus covering obscures it.

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[1] Ill. State Geol. Surv., Bull. No. 41, p. 163 (1920).
Ky. Geol. Surv., ser. 6, vol. 4, p. 38 (1921).
Ky. Geol. Surv., ser. 6, vol. 10, p. 42 (1923).

[2] Ky. Geol. Surv., Miss. Form. W. Ky., p. 73 (1917).

It is entirely possible that other exposures of the Paint Creek in the quadrangle have been overlooked, but it is certain, that through much of the distance where the formation may be sought for, the interval is completely talus covered. In many places the horizon of the Paint Creek is distinctly shown in the topography by the presence of a terrace-like interruption of the hill slopes with the Bethel sandstone below and the Cypress sandstone above.

In the preparation of the geological map it has been assumed that the Paint Creek formation is present throughout the quadrangle at its proper horizon, and a narrow belt of it has been shown at a distance of about forty feet above the top of the Renault limestone.

Lithologic Character. The lithologic character of the Paint Creek formation in the Cave in Rock quadrangle is in strong contrast with the same formation in the Princeton quadrangle, where there is about 100 feet, largely limestone, well exposed. On the other hand the formation closely resembles the Paint Creek of the Golconda quadrangle, and of Hardin County, Illinois, just across the Ohio River. The best exposure of the formation in the quadrangle is along Preacher Creek, one and one-half miles northeast of View, where it is made up of black to gray fissile shale with a thin bed of impure limestone in its lower part, these shales being overlain by thinly and irregularly bedded yellow and brown sandstones, with some black shale partings. On the weathered outcrop these sand beds are porous and they were probably calcareous originally, but with the lime now leached out surficially. Along the valley of Crooked Creek in the Fords Ferry rectangle, extending east from Dunn Spring Church, the Paint Creek is exposed at a number of places. One of the best of these exposures is in a short tributary to the main creek, from the north, about five-eighths of a mile west of Heath School. At this locality eight or ten feet of black, fissile shale are well exposed beneath the Cypress sandstone. At another point, one and one-fourth miles southeast of Dunn Spring Church, on the east side of the creek, a bed of impure limestone is exposed.

The change in the lithologic character of the Paint Creek formation from the Mississippi River sections in Illinois and Missouri, to Caldwell County, Kentucky, is remarkable. In the northwestern portion of its area of exposure it includes a persistent red clay member below, with limestones and calcareous shales above. Across the southern counties of Illinois, from Union to Hardin, the formation is largely a dark shale with some impure, platy limestone layers developed locally, the more eastern outcrops in Hardin County being lacking in limestone and exhibiting thinly bedded sandstones with intercalated black shale layers. In crossing the Ohio River into Kentucky, in the Golconda and Cave in Rock quadrangles, the formation holds the characters exhibited in the adjacent portion of Illinois, but farther south, in the Princeton quadrangle in Caldwell County, the formation thickens and is made up largely of limestone, thin and thick bedded, and oolitic in places, with numerous intercalated beds of shale of various character. Throughout this whole extent, however, the unity of the formation is established by its stratigraphic position between the Bethel and Cypress sandstones or their equivalents, and it has produced its own characteristic fauna throughout its whole extent.

Thickness. In the localities on Preacher Creek northeast of View the exposed thickness of the Paint Creek is about 30 feet, possibly as much as 40 feet, but certainly not more than that. The possible thickness of the formation along Crooked Creek in the Fords Ferry rectangle does not exceed 30 feet and may be as little as 20 feet. From these observations an average thickness in the quadrangle of about 30 feet may be assumed.

Stratigraphic Relations. None of the exposures in the Cave in Rock quadrangle present any important evidence bearing upon the straitgraphic relations of the Paint Creek formation. In southern Illinois there is some evidence to suggest the presence of an unconformity below the formation[1], but it is not conclusive. The stratigraphic relations of the formation with the overlying Cypress are also inconclusive. In the Princeton quadrangle the relations suggest an absence of any stratigraphic break[2] and the same conditions may prevail in the Cave in Rock.

Paleontology. A few fossils have been collected from the impure limestone of the Paint Creek formation on Preacher Creek, and the following species have been recognized:

PAINT CREEK FAUNA FROM PREACHER CREEK.

Michelenia sp.
Cystodictya labiosa Weller
Orthotetes kaskaskiensis (McChesney)
Productus sp.
Spirifer increbescens Hall, var.
Composita trinuclea (Hall).
Sphenotus rectangularis Weller.
Nucula randolphensis Weller.
Leda cf. *chesterensis* Weller.
Euphemus cf. *randolphensis* Weller.
Bellerophon chesterensis Weller.
Holopea ? sp.
Large curved cephalopod.
Fish tooth.

In its general composition this fauna suggests that of the lower Golconda limestone, especially in the several species of Gastropods, and particularly in *Euphemus* cf. *randolphensis.* The single specimen of Michelinia is also a form which has been observed in the Golconda at one or two localities. The presence of *Cystodictya labiosa,* however, is a good Paint Creek marker, for this species has nowhere been observed to range above this formation.

Correlation. The correlation of the Paint Creek formation from the Mississippi River sections in Monroe and Randolph Counties, Illinois, to Caldwell County, Kentucky, is based upon its stratigraphic position between the horizons of the Bethel and Cypress sandstones, and upon its faunal characters. One of the best index fossils is *Cystodictya labiosa,* although this species also occurs sparingly in the Renault. It has nowhere been observed above the Paint Creek. Some good index fossils are found among the Pentremites, but none of these have been found in the Cave in Rock quadrangle, although Cystodictya has been collected.

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[1] Ill. State Geol. Surv., Bull. No. 42, p. 169 (1920).
[2] Ky. Geol. Surv., ser. 6, vol. 10, p. 47 (1923).

CYPRESS SANDSTONE.

Name. The Cypress sandstone was originally named by Engelmann from exposures along Cypress Creek in Union County, Illinois,[1] but it is not the sandstone to which Ulrich applied the name in his Fluorspar Report.[2]

Distribution. In the main the Cypress sandstone in the Cave in Rock quadrangle occupies a north-south belt across the quadrangle, lying a little east of the center. For the most part this lies in the Fords Ferry, Crittenden Spring and Cisco rectangles, but it spreads over into the three rectangles lying to the east of these. The belt attains a width of three or more miles in places, but it is not continuous, being much interrupted by the complex faulting of the area, the most complete interruption being at Marion. Outside of this discontinuous belt there are three other Cypress areas. The first is in the west central portion of the Crittenden Spring rectangle and might almost be considered as a part of the general belt. It is a triangular fault block east of Hurricane Creek, surrounded on all sides by fault blocks of younger formations, and is therefore a block which has remained relatively higher than those surrounding it. The other two areas are both in the Salem rectangle, and are situated in the two down-dropped belts which cross the quadrangle. One of these lies north of the Kirk Knobs, between the Commodore and the Levias faults, and is cut off on the north by a cross fault joining the two longer ones just mentioned. The other area is south of Fairview School, between the Moore's Hill and Clay Lick faults, and extends southward beyond the limits of the quadrangle. Neither of the three areas outside the main belt of the formation exceeds one square mile in extent.

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[1] Ill. State Geol. Surv., Bull. No. 41, p. 175 (1920).
Ky. Geol. Surv., ser. 6, vol. 4, p. 47 (1921).
Ky. Geol. Surv., ser. 6, vol. 10, p. 51 (1923).

[2] U. S. Geol. Surv., Prof. Paper No. 36, p. 53 (1905).

Lithologic Character. The Cypress sandstone of the Cave in Rock quadrangle more nearly resembles that of the Golconda quadrangle to the west, and of Hardin County, Illinois, than it does the Cypress of the Princeton quadrangle. It is a massive sandstone, for the most part in thick beds, becoming more thinly bedded towards the top, and is composed of rather fine, uniform grains of sand. It is brown or yellow brown in color, some of the exposed bluff surfaces being gray, and others being darker than the freshly broken sandstone. In its general appearance the formation is not unlike the Bethel sandstone, and where the thin bed of Paint Creek shale separating the two formations is obscured by talus covering, it is not easy to distinguish the two formations one from the other.

The Cypress of this area is conspicuously different from the thinly bedded or shaly formation of the Princeton quadrangle to the southeast, where it is one of the lesser sandstone members of the section.

In the bank of Cruce Branch of Livingston Creek, east of the Crayne Knobs and a mile or less from the southern border of the quadrangle, a thin bed of impure coal is exposed, its position being above the middle of the Cypress sandstone. The only other locality where coal has been observed in the Cypress is in the lower portion of the formation south of Lola, in the Golconda quadrangle.[1]

Thickness. The Cypress sandstone is one of the thicker sandstone formations in the quadrangle, being comparable with the same formation in the Golconda quadrangle to the west, and being much thicker than the Cypress of the Princeton quadrangle. It is difficult to make an accurate estimate of the thickness of the formation from the surface outcrops. The gorge walls of Clay Lick Creek, above the mouth of Preacher Creek, are wholly of Cypress sandstone. The extreme difference in elevation between the floor of the gorge and the summit of the hill to the east, about one mile east of Cisco School, is about 200 feet according to the topographic map. There must be a considerable thickness of superficial material capping the hill, but there cannot be less than 100 feet or more of the sandstone present which lies above the Paint Creek horizon. On the west slope of the 700 foot hill one half mile south of "The Sinks," near the middle of the Crittenden Springs rectangle, there is a difference in elvation of about 160 feet between the top of the Renault limestone and the summit of the hill, all of which seems to be sandstone. At least 30 or 40 feet at the base must be considered as Bethel, above which there is perhaps a hidden 20 foot interval of Paint Creek. Probably the upper 100 feet of the sandstone is Cypress. The broad sandstone outcrop of over two miles extent to the east from this same hill indicates a thick formation. In the hills to the north and south of Crooked Creek, east of Dunn Spring Church in the Fords Ferry rectangle, where the interval between the Paint Creek and the Golconda can be determined with a fair degree of accuracy, 100 feet seems to be the usual thickness of the Cypress. Taking everything into consideration, 100 feet may be assumed to be about the normal thickness of the formation in this quadrangle.

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[1] Ky. Geol. Surv., ser. 6, vol. 4, p. 48 (1921).

It is surprising to find the apparent absence of this thick sandstone in the only available deep well record in the quadrangle.[1] This well is about three-fourths of a mile east of the public square in Marion, it was started in the Hardinsburg sandstone and was carried to a depth of 1,040 feet and should, therefore, pass through both the Cypress and the Bethel sandstones. The 47 feet of sandstone between 241 and 288 occupies the Cypress-Bethel position, but is far too thin. On the other hand the 189 feet from 52 to 241 is much too great an interval for the Golconda formation as it is commonly developed in this area, and there may be some error in the drillers' record. The Cypress must be present for it is typically developed only a little more than one mile to the southwest.

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[1] Ky. Geol. Surv., ser. 6, vol. 3, p. 108 (1922). The interpretation of this drillers log was made as published before any detailed work had been done in the quadrangle, and before it was known from a field study of the area what sandstone formation the well was started in, which accounts for the incorrect determinations of the formations in the upper portion of the section.

Stratigraphic Relations. Observations in the Cave in Rock quadrangle have afforded no new evidence bearing upon the stratigraphic relations of the Cypress sandstone with the underlying and overlying formations. There is a possible unconformity between the Cypress and the Paint Creek, but such a relation has not been established. There is probably no stratigraphic break between the Cypress and the overlying Golconda formation. In some sections outside of this quadrangle there is definite evidence of a gradual transition from the sand depositing conditions to the shale and limestone conditions of the higher formation,[1] and this condition probably prevails throughout the Ohio Valley district.

GOLCONDA FORMATION.

Name. The name Golconda has come to be thoroughly established in the nomenclature of the Chester formations, for a limestone and shale formation which has its typical development in the Ohio River bluffs above Golconda, Illinois.

Distribution. The Golconda formation with its characteristic lithologic and faunal characteristics has been recognized and mapped in detail from the exposures in the Mississippi River bluffs of Union County, Illinois, to Caldwell County, Kentucky. In the Cave in Rock quadrangle the outcrop of the formation occurs as a narrow, exceedingly sinuous belt, occupying more or less steeply sloping hillsides. This outcrop is not continuous across the quadrangle, but is repeatedly interrupted by the faulting. A large portion of the outcrop is situated in the eastern halves of the Weston, Marion and Crayne rectangles. A considerable portion of the outcrop is also present in the Fords Ferry and northern portion of Crittenden Springs rectangles. In addition to these more or less continuous outcrops there are a number of somewhat isolated ones in the Crittenden Springs, Sheridan, Ciseo and Salem rectangles. Two such outcrops are along the valley of Hurricane Creek, the first one three-fourths of a mile north of Crittenden Springs and the other about the same distance south. In neither of these areas are there extensive exposures, but the character of the shales which have been observed is such as to strongly suggest the Golconda, and the reported section in the hanging wall of the old Columbia mine seems to be of this formation. A third small exposure of the formation is along the Sheridan road between the Franklin and Ada Florence mines, two and one-half miles southeast of Sheridan. At this locality the characteristic fossils of the Golconda, including *Pterotocrinus capitalis,* have been collected. In the southern part of the Sheridan rectangle there is a small outcrop of the Golconda opposite the Miller Mines, which has been certainly identified by the presence of the characteristic plates of *Pterotocrinus capitalis.* West of Levias the Golconda is present in the southwardly sloping hillside in a narrow east-west belt of outcrop, a little over a mile in length between the Commodore and Levias faults. At one locality in this belt a characteristic fossil collection has been secured. The last of the outlying areas of outcrop is a belt in the southeastern part of the Salem rectangle and the adjacent part of the Cisco rectangle, where the formation occupies the escarpment slope below Fairview point between the Cypress and Hardinsburg sandstones, and bounded by the Moore's Hill and Clay Lick faults.

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[1] Ill. State Geol. Surv., Bull. 41, p. 177 (1920).

Lithologic Characters. A large portion of the Golconda formation in the Cave in Rock quadrangle consists of shale. These shale beds vary from completely argillaceous to highly calcareous, and are gray, bluish gray or black in color, with occasionally a bed which is more or less red. In some portions of the formation there are considerable beds of limestone which vary greatly in character, some of them being thin and platy with much interbedded calcareous shale, others being thicker and more massive in character. In general the limestones are more or less coarsely crystalline, though some beds are somewhat compact. In color most of the limestones are rather dark, in many places rusty brown in blotches. On some of them the weathered surfaces are blotched with brown, and some beds are distinctly yellow on the weathered surfaces. In a few localities beds with a reddish color have been observed. One of the most characteristic features of the formation is the highly variable character of both the limestones and the shales.

In most places the actual outcrop of the formation is obscured by the talus slopes in which masses of the limestones may or may not be found mingled with the blocks of sandstone which have come down from the overlying Hardinsburg, but where erosion is sufficiently rapid some good exposures may be seen. Upon some hill slopes, commonly facing to the south, there are glade-like areas upon the Golconda outcrops, which are nearly or quite free from vegetation, except scattered bunches of some coarse grass. Where such glades are underlain by the more calcareous beds some ledges of limestone are commonly exposed, and the weathered out calcareous shales afford great numbers of well preserved fossils characteristic of the formation.

Thickness. It is almost nowhere possible, in the Cave in Rock quadrangle, to determine the actual contacts of the Golconda formation with such a degree of precision as to permit the actual measurement of the thickness of the formation. The thickness can be determined with a fair degree of accuracy, however, from the interval between the outcrops of sandstone below and above, but the upper portion of the underlying sandstone is likely to be covered with talus, and the base of the overlying formation is also likely to be obscured. From many observations, the interval which can be occupied by the Golconda is determined to be from 80 to 100 feet, and there seems to be but little variation in thickness throughout the extent of the outcrop in the quadrangle. This thickness compares favorably with that which has been observed elsewhere, although there are places where the formation is known to be at least 175 feet thick, and in the typical exposures near Golconda it is 130 to 150 feet thick. Elsewhere the formation is known to occupy as small an interval as 60 feet between the two sandstones. Where this variation in thickness is known to exist, it is always the higher beds of the formation which are wanting, and the difference in thickness is doubtless due to the differential erosion of the formation before the deposition of the Hardinsburg sandstone.

Stratigraphic Relations. Little is known of the stratigraphic relations between the Golconda and the Cypress in the Cave in Rock quadrangle, but it is believed that the accumulation of sediments was continuous from one formation to the other without interruption, a condition which seems to exist throughout the Ohio Valley.

The actual contact of the Hardinsburg sandstone upon the Golconda has been best observed in the Cave in Rock quadrangle, in the Ohio River bluff at Weston. At this locality there is a sharp change from the limestone below to the overlying sandstone, with abundant evidence of an unconformable contact. The limestone surface is uneven and there is no mixture of sand with the limestone. This same contact has been observed in one other locality, in a small tributary of Brushy Creek from the north, about three-fourths of a mile from the junction of the main creek with Crooked Creek, a mile northwest of Post Oak School. This contact is not so well exhibited as that at Weston, but the same conditions are shown.

The unconformity at the top of the Golconda formation is general throughout the Ohio Valley, and is well exhibited wherever the Hardinsburg has been observed resting upon the Golconda. The same unconformity doubtless exists also in the Mississippi River sections in Illinois, although there the Hardinsburg sandstone is almost wholly wanting and the Glen Dean limestone rests upon the Golconda.

Paleontology. The paleontologic characteristics of the Golconda formation are sharply defined wherever the formation has been observed in Kentucky and Illinois. The *Pterotocrinus capitalis* fauna in the lower portion of the formation has been recognized from Caldwell County, Kentucky, to the Mississippi River bluffs in Jackson County, Illinois, and a number of entirely characteristic fossil collections have been made from the formation in the Cave in Rock quadrangle. One of the most complete collections is from a locality in the Crittenden Springs rectangle, from a glade a little more than one-half mile northeast of Forest Grove School, where the following species occur:

GOLCONDA LIMESTONE FAUNA FROM NORTHEAST OF FOREST GROVE.

Triplophyllum spinulosum (M.-E. & H.)
Pentremites lyoni Ulrich.
P. canalis Ulrich.
P. platybasis Weller.
P. elegans Lyon.

Pterotocrinus capitalis Lyon.
P. coronarius Lyon.
P. sp.
Acrocrinus sp.
Eupachycrinus 2 spec.
Pachylocrinus sp.
Spirorbis 2 spec.
Hederella sp.
Fistulipora excelens Ulrich.
Eridopora macrostoma Ulrich.
Meekopora clausa Ulrich.
Stenopora cesteriensis Ulrich.
Anisotrypa solida Ulrich.
Fenestella cestriensis Ulrich.
F. tenax Ulrich.
Archimedes swallovanus Hall.
Polypora cestriensis Ulrich
P. spinulifera Ulrich.
Lyropora sp.
Reteporina flexuosa Ulrich.
Septopora subquadrans Ulrich.
Rhombopora sp.
Crania cestriensis M. & G.
Orthotetes kaskaskiensis (McChesney).
Productus ovatus Hall.
Productus parvus M. & W.
Diaphragmus elegans (M. & P.)
Camarophoria explanata (McChesney).
Girtyella brevilobata (Swallow).
Dielasma cf. *illinoisensis* Weller.
Spiriferina spinosa (N. & P.)
S. transversa (McChesney).
Spirifer cf. *leidyi* N. & P.
Martinia sulcata Weller.
Reticularis setigera (Hall.)
Eumetria vera (Hall.)
Cliothyridina sublamellosa (Hall.)
Composita trinuclea (Hall)
Aviculopecten n. sp.

Bellerophon sp.
Naticopsis n. sp.
Conularia sp.
Phillipsia sp.

Correlation. The correlation of the Golconda throughout western Kentucky and southern Illinois has been established by the detailed mapping of the formation from Caldwell County, Kentucky, to Jackson County, Illinois, throughout the whole of which area it is characterized by the *Pterotocrinus capitalis* fauna. Farther northwest, in Randolph and Monroe Counties, Illinois, the Golconda is represented by the lower portion of the Okaw limestone, and although the *P. capitalis* has not been observed north of Jackson County, Illinois, many other characteristic Golconda species are present.

HARDINSBURG SANDSTONE.

Name. The Hardinsburg sandstone was named by Butts from exposures in Breckenridge County, Kentucky.

Distribution. This sandstone formation has been recognized throughout the extent of the Chester Series of rocks in western Kentucky and southern Illinois, and extends even into Randolph County, Illinois, where it is represented by a thin, discontinuous sandstone bed dividing the Lower Okaw from the Upper Okaw limestone.

In the Cave in Rock quadrangle the Hardinsburg sandstone occupies a belt varying in width from less than a mile to more than two miles, and extending southward from the Ohio River bluffs at and below Weston, to the southern border of the quadrangle. For the most part this belt is situated in the western half of the Weston, Marion and Crayne rectangles, but it is more or less interrupted by the complex faulting of the region. Outside of this belt the formation occupies a number of areas of considerable extent. One of these extends southwest from Pickering Hill in a number of detached areas separated by the erosion of valleys tributary to Crooked Creek, and is situated in southern Fords Ferry and northern Crittenden Springs rectangles. Another area of considerable extent lies northwest of Levias, between the Commodore and Levias faults, and there are two smaller areas west of the Commodore fault in northern Salem and southern Sheridan rectangles. The hill just west of the Franklin mine, in the extreme northwestern corner of Cisco rectangle is occupied in part by the Hardinsburg sandstone. One of the largest areas of the formation outside of the more or less continuous belt of outcrops, is situated in the hills between the Moore's Hill and Clay Lick faults, between New Salem and View. In this elevated district the Hardinsburg sandstone forms the surface rock from Fairview School to Cisco School, a distance of nearly four miles.

THE HARDINSBURG SANDSTONE
This siliceous bed rests unconformably upon the Golconda limestone. Ohio River bluff at Weston. Photograph by A. C. Noe.

Many of the high points in the quadrangle are occupied by the Hardinsburg sandstone. The highest point in the area covered by the quadrangle map is Wilson Hill, a mile south of Marion, which reaches an elevation of 843 feet, and is occupied by the Hardinsburg sandstone. The Crayne Knobs, south of Crayne, reach an elevation of 800 feet and are capped by the same formation. Fairview Point, three miles east of Salem, is about 750 feet and is underlain by the Hardinsburg. The highest part of Pickering Hill in the Fords Ferry rectangle runs above 800 feet, and two miles to the north the high point of Cotton Patch Hill rises to the same level, and both of these are Hardinsburg sandstone.

Lithologic Character. The Hardinsburg is one of the most massive, bluff forming sandstones in the quadrangle, and almost throughout the entire extent of its outcrop it rises in an abrupt escarpment above the more gentle slope which is underlain by the Golconda formation. On the summit of the escarpment the surface slopes away gently in a cuesta slope with the dip of the beds. The lower beds of the formation especially, are massive and resemble more or less closely the massive beds of the Cypress sandstone, in fact, in isolated outcrops, where the stratigraphic relations are not shown, it would not be possible to distinguish the two formations. The sandstone itself is moderately fine grained and varies in color from a pure white to yellowish brown The weathered surfaces are commonly yellowish or grayish in color, not at all unlike many Cypress outcrops, though the surfaces are likely to be less frequently reddish brown in color. Some of the purer beds, which are white in color, are suitable for glass sand, one of the best outcrops of this sort being on the lower slope of Wilson Hill just east of Marion. The higher portion of the formation becomes more thinly bedded and in places resembles the Tar Springs sandstone.

The formation exhibits some difference in its lithologic character in the northern and southern portions of the quadrangle. The more massive facies of the formation is present in the tops of the Crayne Knobs and in the bluffs to the east, and this characteristic persists northward to Marion and beyond. In the northern portion of the quadrangle the lower beds of the formation are much less massive, and along the road running north from Forest Grove School, three-fourths of a mile from the school, the lower portion of the formation is thinly bedded and seems to include some shale members. This characteristic is not persistent, however, for at Weston the lower portion of the formation is again massive. Such lateral changes in the lithologic character of the Chester sandstones are not infrequent, and in places they take place in short distances. Along the road from Crayne to Chapel Hill, about one mile northwest of Crayne, a conspicuous shale member in the formation is well exposed. In the south bank of James Fork of Piney Creek, about one mile from the mouth, there is a thin bed of coal in the Hardinsburg sandstone which at some time has been dug for local consumption.

Thickness. At the high point in Wilson Hill, just south of Marion, the lowest ledges of Hardinsburg standstone are exposed about 140 feet below the summit. Because of the talus accumulation the contact with the Golconda is not exposed where this observation was made, and the base of the sandstone may be a number of feet lower, perhaps as much as 20 feet. On the other hand, the accumulation of surficial material on top of the hill doubtless makes the elevation somewhat higher than the summit of the sandstone, and this amount may offset the talus covered basal beds, and the total thickness of the sandstone must approximate 140 feet. In the bluffs east and southeast of Crayne thicknesses of over 100 feet and as much as 140 feet are more or less continuously exposed in a number of places. Similar thicknesses may be measured throughout the quadrangle wherever this sandstone is the surface formation. It is probably nowhere less than 100 feet in thickness and probably has a maximum thickness of about 140 feet. This seems to be a greater thickness for the formation than has been recorded elsewhere. In Pope and Hardin Counties, Illinois, and in Livingston County, Kentucky, the maximum thickness seems to be about 100 feet, and at one locality in Pope County, the formation does not exceed 30 feet in thickness. Throughout these counties, however, the formation is largely a more or less massive sandstone, although locally there are some shale members present. In the Princeton quadrangle, southeast of the Cave in Rock, the Hardinsburg is from 20 to 60 feet thick, and much of it is shale, there being comparatively little massive sandstone in the basal part of the formation.

Stratigraphic Relations. As has been pointed out already, the Hardinsburg rests unconformably upon the Golconda wherever the actual contact between the two formations has been observed. The stratigraphic relations with the overlying Glen Dean limestone are not so clear, for the actual contact between these two formations has nowhere been observed in the Cave in Rock quadrangle. In the Princeton quadrangle, however, this contact is exposed in Walche's Cut, with every indication that the stratigraphic sequence is without interruption,[1] and the same condition may be assumed to continue in the Cave in Rock quadrangle.

Correlation. The outcrop of Hardinsburg sandstone has been followed from Caldwell County, Kentucky, to the Mississippi River sections in Illinois, and it is known to be a continuous formation, underlain and overlain by limestone formations which can be certainly correlated by their fossil contents.

In his latest paper on the Chester section, Ulrich[2] has attempted to synchronize his early generalized section of the "Birdsville formation" with the Chester section as it has been established by the late, detailed work in Illinois and Kentucky, making his "Birdsville No. 3," the equivalent of the Hardinsburg. His early description of "Birdsville No. 3," however, agrees not at all with the Hardinsburg sandstone, being as follows: "Variegated shales, with purple and green colors predominating, occasionally soft and friable and slightly phosphatic ("Litchfield marls"), at other points harder and more or less arenaceous. Apparently quite unfossiliferous, about 50 feet." This description is certainly far removed from anything in the Hardinsburg sandstone in western Kentucky or southern Illinois.

In his geological map of Crittenden and adjacent counties Ulrich[3] has shown a strip of country extending southwest from the Ohio River bluffs between Weston and Fords Ferry, through Pickering Hill to Hurricane Creek, as Mansfield sandstone (=Pottsville), although all of the high hills in this belt are Hardinsburg sandstone, and the lower portions Cypress and Bethel, with the belt of Golconda limestone and shale between. Also along the Tribune road, east from Marion, the same writer shows a strip of undifferentiated Chester upon his map, but states in the text that most of this sandstone is Birdsville No. 1, (=Cypress).[4] There is no Cypress whatever along this road, and the well exposed Hardinsburg and perhaps also the Tar Springs must have been mistaken by him for that formation.

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[1] Ky. Geol. Surv., ser. 6, vol. 10, p. 62 (1923).

[2] Bull. Geol. Sovc., Amer., vol. 33, p. 809 (1922).

[3] U. S. Geol. Surv., Prof. Paper, No. 36, pl. 2 (opp. p. 22), (1905).

[4] U. S. Geol. Surv., Prof. Paper, No. 36; p. 62, (1905).

Glen Dean Limestone.

Name. The Glen Dean limestone has received its name from a locality in Breckenridge County, Kentucky, but it is known to be continuously present throughout the Ohio Valley Chester district, lying above the Hardinsburg sandstone.

Distribution. The Glen Dean limestone has been mapped in detail from Crittenden County, Kentucky, to the Mississippi River sections in Randolph County, Illinois.

In the Cave in Rock quadrangle the main outcrop of the formation occupies a narrow, sinuous belt extending a little southeasterly, from the Ohio River bluffs a mile above Weston, to the southeastern corner of the quadrangle. In the north half of the quadrangle the outcrop is only a little interrupted by the faulting, but in the southern half it is much interrupted, and only along Piney Fork and its branches, and again south and west of Lone Star School, are there any considerable areas of outcrop. In this same general belt of outcrop, but shifted to the west by the faulting, the Glen Dean is present along the Illinois Central Railroad for about two miles north from Crayne.

Elsewhere the Glen Dean comprises the whole of a fault block along Hurricane Creek beginning about a mile north of Crittenden Spring and extending northwest for a little over a mile. Much of the comparatively broad and flat bottom along this portion of Hurricane Creek is due to the presence of this limestone formation. Three-fourths of a mile farther north this same limestone occupies a narrow belt in one of the fault blocks, extending about a mile and one-half northeast from Hurricane Creek, east of the Beard Mines. In the northern portion of the Salem rectangle, between the Franklin and the Corn Mines, over a distance of about three and one-half miles, there are a number of Glen Dean areas of outcrop. A small patch is present in the southern end of the fault block which extends from just east of Tanyard Spring nearly to the old Columbia Mine, and the limestone is also present further north in the same fault block at a number of points where it has been uncovered by the erosion of the overlying Tar Springs sandstone. A narrow belt one and three-fourths miles in length extends from the Siloam fault, nearly opposite the Tanyard Spring, to the Commodore fault, crossing the Levias-Siloam road about one-half mile from Siloam Church. Another belt extends southwest for a mile and one-half, from the Commodore fault, where it crosses Coefield Fork of Deer Creek, to a point just southeast of Hardin Knob. A number of small outcrops are present in the fault blocks west of the Commodore fault, within a mile southeast of Hardin Knob. Northwest of Hardin Knob the Glen Dean occupies a narrow belt lying in a northwest-southeast direction, between the Miller and Big Four faults. The remaining outcrops lie southwest of Marion, in the fault block between the Marion and Clay Lick faults on one side, and the Moore's Hill fault on the other. The top of the formation is exposed in the hillside southwest of the cemetery just west of Marion, and again in the beds of the two tributaries of Crooked Creek which cross the southwestern corner of the city of Marion, and at one point near the corporation limits, west of the Princeton road, a mine shaft has been sunk in the limestone for fifty feet or more. In the public highway near Oak Grove School there are exposures of the Glen Dean limestone which belong with an outcrop which has been uncovered by reason of the erosion of the Tar Springs sandstone by a tributary of Crooked Creek, and a similar inlier, exposed by erosion, is present along a tributary of Clay Lick Creek about half way between Oak Grove and Cisco Schools. East and west from Cisco School, a continuous belt of the Glen Dean limestone some two miles in length, crosses the fault block, some of the best exposures being along the bed and banks of Clay Lick Creek three-fourths miles northeast of the school. A belt of the formation also encircles the 660 foot hill three-fourths mile south of Cisco School.

Lithologic Characters. The Glen Dean formation in the Cave in Rock quadrangle includes a much larger percentage of limestone than does the Golconda formation, although the lithologic characters exhibit considerable change in passing from the southern to the northern portions of the outcrop. In the southeastern part of the quadrangle the formation contains less limestone than it does in the exposures near the Ohio River. One of the best exhibitions of the formation in this portion of the quadrangle is on the Enon road about one-half mile northwest of Piney Church, where the lower half of the formation is essentially limestone and the upper half is shale. About a mile and one-quarter west of this outcrop the Glen Dean forms the floor of the second valley west of Lone Star School, tributary to Butler Creek. Only a few actual outcrops are exposed in this valley, although limestone ledges and washed out material may be observed at intervals in the tributary and in the floor of Butler Creek itself. Much of the formation is probably shale. Most of the limestone in these and neighboring localities is rather coarsely crystalline in texture, and gray in color, it being more uniform in character and generally lighter in color than the limestones of the Golconda formation.

In the northern portion of the quadrangle good Glen Dean limestone exposures are present in the Ohio River bluffs a mile and one-fourth above Weston, and in the hills east and northeast of the same town. In these outcrops the formation seems to contain much less shale, although shale beds are probably present between the limestone ledges, and the limestone is lighter gray to nearly white in color, and rather more uniform in texture.

Along much of the belt of outcrop actual exposures are scarce, but tumbled masses of limestone on hillsides and in gullies may be found at more or less frequent intervals. The outcrops in the outlying areas of the Glen Dean formation resemble those along the more continuous belt, both as to exposures and as to lithologic character.

The Glen Dean throughout the Cave in Rock quadrangle, even in the southeastern portion of the area, includes much more limestone than is present in the formation in the Princeton quadrangle where it is almost wholly shale, but in tracing the formation westward into the Golconda quadrangle, and northward into Hardin County, Illinois, the characters exhibited in the Cave in Rock quadrangle persist, the greatest amount of uniform, gray, crystalline limestone being present in the region east of Weston and in the exposures across the Ohio River in southeastern Hardin County.

Thickness. The best exposures of the Glen Dean limestone in the quadrangle exhibit a thickness of about 60 feet. The thickness can best be determined in some of the sections east of Weston, but even here the actual contacts with the underlying and overlying sandstones are not exposed, but the possible interval which may be occupied by the formation nowhere varies much from 60 feet. In the southeastern portion of the area the outcrop on the Enon road northwest of Piney Church, shows an exposure of fifty or perhaps sixty feet. These thicknesses agree well with determinations which have been made generally throughout western Kentucky and southern Illinois.

Stratigraphic Relations. The actual contacts of the Glen Dean limestone with the underlying Hardinsburg and the overlying Tar Springs sandstones, have nowhere been observed in the Cave in Rock quadrangle. There is no reason to believe that any unconformable relation exists between the Glen Dean and the Hardinsburg, but the sand of the Tar Springs formation seems to be introduced abruptly and there may be a stratigraphic break at this horizon.

Paleontology. No extensive collections of fossils from the Glen Dean limestone have been secured in this quadrangle, but the species which have been observed in the field are those to be expected from the formation. Among the species recognized are *Pentremites pyramidatus* and *Prismopora serrulata,* two forms which have proven to be highly characteristic of the formation. The specimens of Prismopora are not so abundant in this region as in some other Glen Dean localities, but their presence, even in small numbers, is an important factor in the determination of this limestone.

Correlation. The stratigraphic position of this limestone in the Chester Series, and the presence of such fossils as *Pentremites pyramidatus* and *Prismopora serrulata,* establishes beyond question the identity of this formation with the Glen Dean limestone of the Ohio and Mississippi valleys.

TAR SPRINGS SANDSTONE.

Name. The name of this formation was first applied by Owen in Breckenridge County, Kentucky, and in late years it has come to be widely used in the general section of the Chester Series.

Distribution. The Tar Springs is one of the widely distributed sandstone formations of the Chester Series in the Ohio Valley, and is recognized as far west as Union and Jackson Counties, Illinois. It seems to be absent, however, from the Chester section of Randolph County, Illinois.

In the Cave in Rock quadrangle the distribution of the formation conforms in general with that of the other members of the Chester Series, there being a discontinuous north-south belt across the eastern rectangles, with a number of outlying areas farther west. The formation is exposed in the Ohio River bluffs one and one-fourth miles above Weston, it rises to the south and caps some of the hills east of that town. The most continuous portion of the north-south belt is for a distance of about seven miles between the Heath School fault and the Moore's Hill fault, the average width through this distance being about one mile. Between the Moore's Hill fault on one side and the Marion and Clay Lick faults on the other, a great tongue of Tar Springs sandstone extends to the southwest for a distance of nearly eight miles, underlying most of the city of Marion, and being well exposed westward along the Salem

THE TAR SPRINGS SANDSTONE
This exposure is to be seen at Cochran Hill, on Marion-Princeton Road. The thinly bedded character of the formation is well exhibited.

road as far as Moore's Hill. South of the Marion fault the sandstone is again well exposed along the Tribune road, starting about two miles east of Marion and continuing for a mile. Southeast from this road it caps the hills on either side of Piney Creek and those lying between the several branches of the creek. South of the Chapel Hill fault the outcrop is shifted by faulting for several miles to the west, and is exposed along the Marion-Princeton road from Cochran Hill to Crayne. South of the Crayne fault the areas of Tar Springs sandstone are more or less broken up and lie between Butler Creek and the southeastern corner of the quadrangle.

West of the series of outcrops which have been mentioned, the Tar Springs sandstone occupies the whole or a part of a number of fault blocks in the down-dropped segment lying between the Commodore fault and its successors to the southwest on one side, and the Heath School, Crittenden Springs and Levias faults and their successors on the other side. Two blocks in the northwestern portion of the Crittenden Springs rectangle, lying east of Hurricane Creek and south of the Beard mines, expose a considerable area of the formation. In the more northern of the blocks the sandstone caps a belt of Glen Dean limestone, but in the larger southern one the Tar Springs seems to make up the entire block. The remaining areas of outcrop are mostly in the Salem rectangle, but they do extend northward and northeastward into the Sheridan and Crittenden Springs rectangles. The high hill lying west of the Franklin mine and extending northward for about a mile, is capped by the Tar Springs, and the sandstone outcrops along the Marion-Sheridan road at Tanyard Spring are of this formation. A belt of Tar Springs one-half to three-fourths of a mile wide, south of Coefield Fork of Deer Creek, extends westward from the Siloam fault at Tanyard Spring, to the Commodore fault, much of the highway for a mile west of Siloam being over this sandstone. West of the Commodore fault and south of the Big Four fault, the Tar Springs occupies the greater portion of the fault block extending in a southwesterly direction for over a mile and one-half. Towards the south end of this block the sandstone gives place to the underlying Glen Dean limestone, and at the north the Vienna limestone overlies the sandstone. Two smaller blocks, south and southwest of the one last mentioned, are also in large part of Tar Springs sandstone. Still farther southwest, across the line in Livingston County the same formation makes the surface outcrop in two fault blocks lying east of Sandy Creek.

Lithologic Characters. The Tar Springs is in general a less massive sandstone than either the Hardinsburg or the Cypress. The thinly bedded character of the formation may be well seen at Cochran Hill, half way between Marion and Crayne, but it does include some more massive beds locally. A number of good exposures of the formation are present along the Marion-Salem road between Marion and Moore's Hill, and most of these exhibit the thinly bedded character of the formation. The contrast in character between the Tar Springs and the Cypress is well exhibited along the Fords Ferry road out of Marion, the exposures for a mile and one-half from the square in Marion being Tar Springs, but for the last quarter mile before reaching the covered bridge over Crooked Creek, the Cypress sandstone ledges, very different in character, are well exposed. In places a considerable portion of the Tar Springs is a sandy shale or even a more or less clay shale locally, this shaly phase being well exhibited along the road from Siloam to Salem, a mile southwest of Siloam Church. In the fault block east of Sandy Creek, a mile and a half north of Salem, the shaly character of the Tar Springs is well exhibited in some of the ravines cutting the hill, and it is largely on account of this lithologic character that the sandstone of the block is referred to the Tar Springs, there being no limestone present to assist in identifying the sandstone. Some portions of the formation are made up of thin beds which are finer grained, denser, and more compact than common in the sandstone beds of the Chester, and they exhibit a distinctly wavey or hummocky bedding, and in places these beds include concretion-like masses with rounded and smooth surfaces, some of these masses being a foot or more in cross section.

The color of the Tar Springs sandstone is yellowish, as is the case with most of the Chester sandstones, but in places it is some paler yellow than the Hardinsburg or the Cypress. In many localities however, the formation exhibits a distinct chocolate brown color especially where its thin or shaly beds are weathered out.

Thickness. The Tar Springs is the third one of the thick sandstones in the Chester Series of the Cave in Rock quadrangle. There is perhap no locality in the area where the entire thickness of the formation can be measured directly, but in various places the relations of the formation with the underlying Glen Dean limestone and to the topography is such as to indicate a thickness of as much as 100 feet, and locally the thickness seems to be even greater. In the hill lying three-fourths of a mile north of the south line of the quadrangle, and one and one-half miles west of the east boundary, whose summit rises above the 760-foot contour, there must be more than 100 feet of the Tar Springs sandstone present, and possibly as much as 160 feet. Northeast of Marion for a distance of three miles, in the belt lying northwest of the Illinois Central Railroad, the formation seems to be thinner than common, but it is possible that the dip of the beds is here sufficient to account for the full thickness.

The observations in this quadrangle agree well with those in the adjoining areas to the west and north, but in the Princeton quadrangle the formation seems to be somewhat thicker than in the Cave in Rock, perhaps exceeding 200 feet at least locally.

Stratigraphic Relations. The possibility of the presence of an unconformity at the base of the Tar Springs sandstone has already been considered, but there is no conclusive evidence concerning the relations of the two formations in the Cave in Rock quadrangle. No section in the quadrangle has exhibited the actual contact of the overlying Vienna limestone upon the Tar Springs, but in all probability there is no stratigraphic break at this horizon.

Correlation. The correlation of the Tar Springs sandstone throughout the Ohio Valley is established by the careful tracing and detailed mapping of the formation which has now been carried from Caldwell County, Kentucky, to the Mississippi River in Union and Jackson Counties, Illinois.

VIENNA LIMESTONE

Name. The Vienna limestone was first named from outcrops which are present at Vienna, Johnson County, Illinois.

Distribution. This formation has been recognized throughout the area occupied by the Chester Series in the Ohio Valley.

In the Cave in Rock quadrangle, as elsewhere, the areal extent of the formation is small as compared with most of the others in the series, because of its very limited thickness. There is a continuous belt of outcrop in the Weston and Marion rectangles, extending from the Heath School fault to the Moore's Hill fault. This belt is very narrow, in general not over one-eighth of a mile, but actual exposures of the limestone or an abundance of the characteristic residual cherts of the formation may be seen at more or less frequent intervals throughout its extent. There are good exposures along the road from Weston to Rodney, and on the road leading west from Baker School House, and again in the valley tributary to the easternmost branch of Camp Creek which heads west of the Henderson road a mile and one-quarter north of the junction of this road with the Weston road. One of the best exposures in the district is in the hillside west of the Henderson road a quarter of a mile south of Mattoon, and three-fourths of a mile south of Mattoon the limestone is exposed in the road. The limestone is exposed less conspicuously elsewhere along the line of outcrop, and at various other places numerous fragments of the characteristic chert are washed out in the surficial material. The formation outcrops in two ring-like belts, joined together, a little over a mile in length, about two miles west of the east boundary of the quadrangle, between the Baker School-Weston road and the Mattoon-Weston road.

Between the Moore's Hill fault and the Marion fault, in the southwestern part of the Marion rectangle, the Vienna limestone outcrop trends from the northeast to the southwest. Excellent exposures are present under the bridge three-eighths of a mile west of Going Spring School, also at the spring a few rods west of the bridge and other less conspicuous exposures are present near by. No other good exposures along this belt have been observed except in the proximity of Marion, although the weathered-out chert may be seen in places. At Marion very good exposures are present in the south bank of Rush Creek within and just beyond the corporation limits of the town, and the limestone may be seen at the side of the Henderson road where it crosses the branch of Rush Creek just beyond the railroad crossing, near the northeast corner of the town limits. On the Tribune road, one and one-fourth miles east of the Marion courthouse, ledges of the Vienna limestone cross the road.

South of the Marion fault the Vienna outcrop is shifted about three and one-half miles to the east because of the faulting, where it occupies a narrow belt similar in width to those farther north, which trends southeast and leaves the quadrangle near the northeastern corner of the Crayne rectangle, just north of Piney Creek. In this belt the limestone is exposed a quarter of a mile north of the Tribune road and beyond. To the southeast, for the last half mile of the belt before it crosses the east boundary of the quadrangle, there are numerous excellent exposures, especially where the belt crosses the north-south road three-eighths of a mile west of the quadrangle boundary, and in the road turning to the east a half mile south of the Marion-Crayne rectangle boundary, and between these two points. South of the outcrops last mentioned, the Vienna limestone is present in a small area just east of Piney Church, and although no good exposures of the limestone can be seen the characteristic chert fragments are present in a number of places.

The Vienna limestone outcrops in the valley of Clay Lick Creek two miles southwest of the courthouse in Marion, in the angle between the Marion and Clay Lick faults. The actual exposure is very limited although the ledges can be seen at one or two places, but the characteristic chert is scattered about generally. Along the road turning south from the Marion-Salem road, one-half mile east of Oak Grove School, the characteristic loose cherts can be seen at a number of points from one-half mile to a mile from the junction point. The presence of these cherts doubtless indicates the existence of a capping of Vienna over a portion of this hill slope.

In the western portion of the Crittenden Spring rectangle, starting at a point about three-fourths of a mile north of the springs, the Vienna limestone outcrops for over a mile along the base of the hill lying southwest of the Hurricane Creek Valley, and at a number of points good exposures of the formation can be seen.

Another narrow belt of outcrop of the Vienna limestone is present just north of the Coefield Fork of Deer Creek, between the Siloam and Commodore faults. A good exposure of the limestone may be seen at the road corner between Siloam School and Siloam Church. This belt is about one mile in length and has either exposures of the limestone or weathered-out fragments of the chert at a number of points. The characteristic loose cherts of the formation are present at two localities along the road southwest from Siloam Church, about one-fourth mile south of the creek, which must be due to the presence of the Vienna capping the shoulders of the hill which is Tar Springs sandstone in the main. Just northeast of the Siloam fault the Vienna limestone must be present almost opposite the outcrop of the same formation on the other side of the fault. No real exposures of the formation have been seen, but both the higher and lower formations are present in this fault block, and the Vienna must be present, covered by the surficial materials.

There is a small exposure of Vienna limestone in the north bank of Coefield Fork of Deer Creek, a little over one-fourth of a mile above the Big Four Mine, just west of the north-south road crossing the creek at this point. This is a part of an area of outcrop occupying the bottom land in the triangular fault block between the Big Four and Hardin Knob faults. Northeast from this block the Vienna continues as a narrow belt adjacent to fault No. 14.

The westernmost occurrence of the Vienna in the quadrangle is about a half mile east of the Salem-Tolu road, just north of the crossroad two and three-fourths miles north of Salem. At this locality the presence of the formation is shown by the characteristic cherts in a number of gullies washed in the hillside, and by some shale beds.

Lithologic Characters. The Vienna limestone in the Cave in Rock quadrangle is entirely similar to the formation as it occurs generally throughout the Ohio Valley, the uniformity of this thin limestone bed from Caldwell County, Kentucky, to Union County, Illinois, being really remarkable. The formation consists of both limestone and shale, the lower portion commonly containing the greater portion, if not the whole of the limestone, the higher portion being shale. The limestone is particularly characterized by the high content of silica which is manifested in the form of chert, and as a porous, siliceous rock which is a weathering product of a siliceous limestone from which the lime has been leached. One of the commonest occurrences of the formation in the quadrangle is in the form of the characteristic cherts in the residual deposits. The cherts break up into subcubical fragments which are very resistant to destructive agencies and whose presence proves the existence of the formation in many places where not a fragment of limestone or shale is exposed. The shales of the formation are gray or dark in color, and are rarely exposed in the quadrangle.

Thickness. The Vienna is one of the thin formations in the Chester Series, and is as persistent in this respect as in its lithologic characters. There is no locality in the Cave in Rock quadrangle where the entire thickness of the formation has been observed. The limestone portion of the formation probably nowhere exceeds 20 feet, and there may be as much shale overlying the limestone. In the Princeton quadrangle about 50 feet of Vienna are known to be present, and the thickness in the Cave in Rock may be equal to or somewhat less than that.

Stratigraphic Relations. The Vienna probably rests upon the Tar Springs sandstone with complete conformity, which seems to be the condition throughout western Kentucky where the formation has been mapped. It also passes without stratigraphic break into the overlying Waltersburg sandstone.

Paleontology. The only collection of fossils from the Vienna limestone which has been made in the Cave in Rock quadrangle, is from the dump of a prospect hole near the head of Clay Lick Creek about two miles southwest of Marion courthouse, where the following species have been found:

FAUNA OF VIENNA LIMESTONE TWO MILES SOUTHWEST OF MARION.

Tripophyllum spinulosum (M. E. & H.)
Pentremites cherokeeus Hall?
Archimedes sp.
Orthotetes kaskaskiensis (McChesney).
Productus ovatus Hall.
Diaphragmus elegans (N. & P.)
Camarophoria explanata (McChesney).
Girtyella brevilobata (Swallow).
Dielasma sp.

Reticularia setigera (Hall).
Composita subquadrata (Hall).
Laevidentalium illinoiensis (Worthen).
Naticopsis sp.
Holopea sp.
Stroboceras? sp.

There is nothing particularly distinctive in the Vienna fauna, for all of the species have a considerable range in the Chester Series.

WALTERSBURG SANDSTONE

Name. The Waltersburg sandstone was first differentiated in Pope and Johnson Counties, Illinois, and was named from a locality near Golconda.

Distribution. In its general distribution the Waltersburg has been recognized throughout the area occupied by the Chester Series in the Ohio Valley, from Caldwell County, Kentucky to Union County, Illinois. In the Cave in Rock quadrangle it follows the distribution of the underlying Vienna limestone, the two formations together making a belt which is commonly less than a quarter of a mile in width, and it will not be necessary to repeat a description of this distribution. In a number of places along the line of outcrop the belt is notably broader than usual. Such a broader belt which is in places as much as one-half mile in width, extends for about three and one-half miles between the Klondike and Moore's Hill faults, in the northeastern portion of the Marion rectangle. The reason for the greater width of outcrop in this location is that the outcrop occupies a dip slope just west of the headwater branches of Brushy Creek. Another area where the outcrop has a much greater width than common is four miles due east of Marion, south of the Tribune road, at and near the eastern boundary of the quadrangle and along the line between the Marion and Crayne rectangles. The width of the outcrop here, along the edge of the quadrangle, is about one mile, this excessive width being due to the much greater thickness of the formation at this locality than elsewhere in the quadrangle.

An excellent exposure of the formation may be seen along the Henderson road a little more than one-fourth mile south of

Mattoon, and another good exposure is at the church just west of Repton. From a point a little more than a mile from Marion on the Henderson road, the public highway follows a terrace-like bench formed by this sandstone for about a mile, with a number of excellent exposures. A very characteristic exposure of the Waltersburg is present in the northern end of the railroad cut north of the Tribune road, in the eastern part of Marion. Elsewhere in the quadrangle the actual exposures of the formation are limited although the presence of the sandstone is shown by the characteristic, weathered out fragments which occur in the residuum.

Lithologic Characters. In its general distribution the Waltersburg sandstone exhibits two widely distinct facies. In its area of typical development in Johnson and Pope Counties, Illinois, it is a massive, bluff forming sandstone, locally not unlike the Cypress in aspect. The region occupied by this massive facies of the sandstone is limited in extent, and generally the formation consists of evenly and thinly bedded sandstone which has the habit of being jointed in two directions in such a manner as to give origin to sliver-like fragments ranging in length from an inch or more to over a foot in length, the width and thickness

A TYPICAL EXPOSURE OF WALTERSBURG SANDSTONE.
This outcrop is on the Henderson Road, one mile south of Mattoon

of the slivers being from one to three inches. Associated with the sandstone beds there are beds of black shale.

In the Cave in Rock quadrangle both facies of the Waltersburg are present. In most of the outcrops it is the sandstone which breaks up into the sliver-like masses which is present. In general there are two beds of such sandstone, five feet more or less in thickness, separated by dark shales, perhaps ten feet in thickness. Beneath the lower of these sandstone beds there is a much thicker body of shale which passes down into the Vienna limestone, and the line between the two formations is more or less arbitrarily drawn. Where this thin bedded Waltersburg exists below the influence of surface weathering conditions, it is dark colored on freshly broken surfaces because of the large amount of carbonaceous matter present, but where weathered it is brown or yellow in color, but with the surfaces along the joints in many places covered with a reddish crust. This very typical expression of the formation may be seen at a number of places along the public highway between Marion and Mattoon.

Three and one-half miles east of Marion, on the Tribune road, there is a good exposure of the Waltersburg sandstone which has a somewhat different expression from that described above. It is a thinly bedded yellow or tan colored sandstone without the distinct tendency to break into sliver-like fragments, and without shale beds, although there is shale beneath the sandstone, similar to that seen elsewhere. South and east of this locality, along the road turning south from the Tribune road three-fourths of a mile from the east boundary of the quadrangle, and again turning to the east about three-fourths of a mile from the road corner, the broad belt of Waltersburg which has been mentioned, is encountered. Some of the best exposures in this area are just off from the Cave in Rock in the edge of the Providence quadrangle. The sandstone is in massive beds, quite unlike the usual character of the formation and more closely similar to the massive beds of the formation as it occurs in Pope and Johnson Counties, Illinois. This sandstone may be seen in the road and also in the valley of the first tributary to Piney Creek south of the Tribune road. Most of this sandstone is yellow brown in color, similar to most of the more massive

Chester sandstones, but some beds have been observed with a peculiar pink color which is entirely similar to some portions of the massive facies of the formation in Pope County, Illinois.

Elsewhere in the Cave in Rock quadrangle the Waltersburg resembles the usual character of the formation as exposed along the Henderson road.

Thickness. The thickness of the beds which should be included in the Waltersburg sandstone is somewhat uncertain. In its more usual expression in the quadrangle, the two sandstone beds with the shale between do not exceed about 20 feet, and it is a question whether the shales between these sandstone beds and the siliceous limestone beds of the Vienna should be included with the underlying or overlying formation. It is easier to determine the thickness of the interval which includes the Vienna and Waltersburg together, than to determine the thickness of either formation alone. The usual thickness of the two formations is about 60 feet, in places perhaps no more than 50 feet, with not more than 20 feet above the main mass of shale which lies above the basal limestone. In the district south of the Tribune road, at the eastern border of the quadrangle, however, the sandstone is much thicker. The exact thickness can not be determined from the scattered outcrops, but it must be as much as 60 feet, and with this increased thickness is associated the different lithologic character of the formation which has been described, this greater thickness of the formation being comparable to the increased thickness which exists in that part of Pope and Johnson Counties, Illinois, where the formation was first differentiated and named.

Stratigraphic Relations. No new evidence has been secured in the Cave in Rock quadrangle bearing upon the stratigraphic relations of the Waltersburg sandstone. There is believed to be no stratigraphic break between the formation and either the underlying Vienna, or the overlying Menard limestones.

Correlation. The persistent lithologic character of the Waltersburg sandstone throughout the Chester area of the Ohio Valley in western Kentucky and southern Illinois, together with the identity of the underlying and overlying limestones in the same region, establishes the correlation of the bed at least from Caldwell County, Kentucky to Union County, Illinois.

MENARD LIMESTONE

Name. The type locality for the Menard limestone is in the vicinity of the Southern Illinois Penitentiary at Menard, near Chester, Illinois, where it is well exposed in the upper portion of the Mississippi River bluffs.

Distribution. The Menard limestone is present throughout the Chester area of western Kentucky and southern Illinois, wherever the proper portion of the section is exposed. In the Cave in Rock quadrangle the greater portion of the outcrops are present in the three eastern rectangles, where there are many excellent exposures. The narrowly wedge-shaped fault block northeast of Weston, bounded by Heath School fault on the east, fault No. 33 on the west, and fault No. 2 on the north, is nearly all Menard limestone, and from the southern extremity of this block a continuous belt of the formation, in places more than one-half mile wide, continues for a little more than seven miles to the Moore's Hill fault, passing a little west of Baker School, east of Mattoon, and through Repton, with a slight offset, less than the width of the outcrop, at the Klondike fault. Throughout the extent of this outcrop there are many excellent exposures of the formation. For the most part this outcrop occupies a rather steep, westerly facing hillslope, and wherever a ravine is cut down the slope and wherever a public highway crosses it, good exposures are almost sure to be present.

South of the Moore's Hill fault the Menard outcrops are much less continuous. Between the Moore's Hill and Marion faults, the belt of outcrop lies in a northeast-southwest direction, from the eastern edge of the city of Marion to the Going Spring School, and for nearly a mile beyond. This belt of outcrop occupies the steeply sloping hillside lying southeast of the Illinois Central Railroad, northeast from Marion, and the basal beds with their characteristic fauna are well exhibited in the railroad cut beside the Tribune road in the eastern part of Marion.

South of the Marion fault the Menard outcrop is shifted to the east. It is well exhibited on the Tribune road four and three-fourths miles east of Marion, and continues to the eastern boundary of the Cave in Rock quadrangle and beyond, to Tribune. The formation is particularly well exposed in this area in the hills both to the north and to the south of the Tribune road, and it was from these exposures that the Tribune limestone was named by Ulrich under the mistaken supposition that it was the same limestone as that east of Princeton, Kentucky, which is now known to be Paint Creek.

South of the Chapel Hill fault the Menard limestone is exposed in a number of smaller, scattered areas. South of Pilot Knob it forms the bed of Butler Creek for a distance of more than a mile, and it is also exposed on both sides of the fault block lying between Butler Creek and Piney Fork Church. Along a branch of Butler Creek from the south, the Menard limestone underlies the steep hillslope northeast of Piney Church, for more than a mile. Farther up the valley of Butler Creek, the Menard limestone is exposed in the different fault blocks between the Lone Star and the Crayne faults, the most extensive area of outcrop being in the block next west of the Lone Star fault and north of Butler Creek. Between the Chapel Hill and Crayne faults the Menard occupies a belt more than one-half mile in width in places, lying in general about three-fourths of a mile east of the Marion-Princeton road. In this area, especially in the southeastern part, there are some excellent exposures of the formation.

In the extreme southeastern corner of the quadrangle, in the much faulted belt which extends in a northeast-southwest direction, there are two small areas of Menard limestone separated by a hill of Palestine sandstone beneath which the limestone is certainly continuous.

In the more western portion of the quadrangle there is a belt of outcropping Menard limestone more than a mile long, in the hillslope facing Hurricane Creek, whose south end is a little more than one-half mile north of Crittenden Spring. Along this belt of outcrop many good exposures of the limestone may be seen. North of this hill in the valley of Hurricane Creek, there is a small area less than one-fourth mile in width in a triangular fault block, which has been mapped as Menard, where a single obscure exposure of the limestone has been seen to possess the characteristics of this formation, although no fossils have been observed. The floor of the valley of Hurricane Creek, for a half mile north and three-fourths of a mile south of Crittenden Spring is apparently underlain by the Menard limestone. This valley, through the extent indicated, is bounded by faults on the two sides, these faults being one-fourth mile or less apart. There are few exposures of the limestone in this fault block, but it may be seen in the public road one-fourth mile southwest of the springs, and again in the bank of the creek about three-fourths of a mile southwest of the spring.

In the hillslope back of Siloam School, and extending for about a mile to the northeast, the Menard limestone is present, and in the northern portion of the area there are numerous characteristic exposures of the formation. A considerable area of Menard limestone is present in the angle to the south, between the Siloam and Commodore faults, the best exposures being along the southern border of the area, just north of Coefield Fork of Deer Creek, where the length of the outcrop is over three-fourths of a mile. To the north there is a dip slope with little or no exposure.

Farther west, in the southern part of Sheridan and northern Salem rectangles, a considerable area of Menard limestone occupies the two forks of a valley tributary to Coefield Fork of Deer Creek which joins the main creek from the south just above the Big Four mine. The last Menard area to be mentioned lies along the Salem-Tolu road between two and three miles north of Salem, this area has a width between faults of one-half to three-fourths of a mile, and in it there are a number of excellent, typical exposures of the formation.

Lithologic Characters. The Menard is perhaps the most uniform, lithologically, of any of the thick Chester limestones throughout its entire extent from Caldwell County, Kentucky, to the Mississippi River. In color it is bluish gray to nearly black, the darker colors being less usual in the Cave in Rock quadrangle. In texture the rock is mostly dense, compact and hard, and when broken much of it has a tendency to splinter in sharp edged fragments. The individual beds are not thick, commonly being less than one foot, and their surfaces tend to be irregularly undulatory or hummocky, with shaly partings separating the successive beds. The shale partings are commonly thin as compared with the limestone beds, but in places there are more pronounced shale beds several feet in thickness, and in the upper portion of the formation there is rather generally one more than usually thick shale bed, which may be 15 feet or more. The shales are commonly bluish or gray in color, and in places are fossiliferous. The weathered surfaces of the limestones are commonly smooth and light colored.

In the basal portion of the formation there are twenty feet, more or less, of strata which contain a considerable amount of calcareous shales, and the shales and platy limestones of this portion of the formation are highly fossiliferous in places. These beds are likely to be more or less obscured by talus accumulations in the natural outcrops of the formation but they were well exhibited in the Illinois Central Railroad cut, north of the station in Marion, when that excavation was first made, although at the present time the surfaces of the cut are largely covered with material which has washed down the sides.

Thickness. Nowhere in the Cave in Rock quadrangle, where the entire thickness of the Menard is present, can the interval occupied by the formation be less than 100 feet, and in places it is clearly considerably more than this, perhaps as much as 140 feet. This thickness corresponds well with that of the same formation in the Princeton quadrangle, but is somewhat greater than that which has been commonly recognized in southern Illinois. The total thickness of the formation in the Kentucky portion of the Golconda quadrangle has nowhere been determinable.

Stratigraphic Relations. There seems to be no interruption in the sedimentary record in passing from the Waltersburg sandstone into the Menard limestone, but at the summit of the Menard there is probably an unconformity. The presence of such an unconformity is suggested by the abrupt change from the limestone into the basal, massive beds of the Palestine sandstone. Also the apparent difference in thickness of the Menard in passing from Caldwell and Crittenden Counties, Kentucky, into southern Illinois, may be due to the differential erosion of the formation preceding the deposition of the sandstone. The actual contact of the Palestine sandstone upon the Menard has nowhere been observed in this quadrangle.

Paleontology. The fossils of the Menard from the Cave in Rock quadrangle are entirely similar to those which are present in the same formation elsewhere. The most fossiliferous portion of the formation is at the base, where there is a zone particularly characterized by *Pentremites fohsi*, and the large wing plates of *Pterotocrinus menardensis.* Both of these forms have been collected from the railroad cut in Marion, in fact this excavation is the locality from which one of the co-types of *P. fohsi* was secured. Another species which has been found in the Menard limestone throughout the extent of the formation in the Ohio and Mississippi valleys, is *Sulcatopinna missouriensis.* This species is not restricted to any special horizon in the formation, nor it is entirely restricted to the Menard, although it is most characteristic of this limestone. This species has been observed at several localities in the Cave in Rock quadrangle, and doubtless could be found in many other places if search were made.

Correlation. The correlation of the Menard limestone throughout the entire Chester area of western Kentucky and southern Illinois is based upon the actual tracing of the formation in connection with the detailed mapping which has been accomplished, as well as upon the similarity of the faunas throughout.

In his early report Ulrich[1] apparently had no clear conception of this formation. He states definitely that the outcrop in the railroad cut in Marion is "Birdsville No. 2" which should be the Golconda limestone, a formation at least 400 feet lower in the section than the actual position of the beds in question. The Menard at Tribune he believed to be the same as the Paint Creek in some other parts of the district, the difference in position of these two limestones being at least 500 feet. Not only are these limestones with which the Menard was correlated by Ulrich widely separated from it stratigraphically, but the faunas of the Menard and both of these other limestones are widely different.

PALESTINE SANDSTONE.

Name. The Palestine sandstone was named from the exposures in Randolph County, Illinois, where the formation was first differentiated.

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[1] U. S. Geol. Surv., Prof. Paper, No. 36, p.

Distribution. The distribution of the Palestine sandstone is coextensive with the Chester Series in western Kentucky and southern Illinois, having been recognized and mapped in detail from Caldwell County, Kentucky, to Randolph County, Illinois. In the Cave in Rock quadrangle the greater part of the outcrop of the formation lies in the three eastern rectangles. From the Heath School fault east of Weston, to the Moore's Hill fault southeast of Repton, there is a continuous belt of Palestine sandstone, in some places being more than a mile in width, the width of the outcrop being dependant upon the topography. This belt lies just east of the belt of Menard limestone which has been described. Excellent exposures of the formation are present along the Henderson road for a mile or more south of Baker School, and the sandstone is commonly more or less well exposed at the summit of the bluffs whose lower slopes are underlain by the Menard limestone.

In the fault block lying between the Moore's Hill and Marion faults, the Palestine sandstone caps the hill lying east of the Illinois Central Railroad track and the public highway to Henderson, starting at a point one and one-half miles northeast of Marion, and continuing for two and one-half miles, whose lower, northwesterly directed slope is occupied by the Menard, Waltersburg and Vienna formations. The abrupt termination of the north end of this hill, a little less than a mile north of Going Spring School and one and one-half miles southwest of Repton, is due to the presence of a fault diverging from the Moore's Hill fault and extending nearly east.

In the angle between the Marion fault and fault No. 82 diverging from it to the northeast at a point two miles east of Marion, an area of sandstone has been mapped as Palestine which is possibly a sandstone bed in the lower portion of the unit next above the Palestine, perhaps being the equivalent of the Degonia sandstone.

Between the Marion and Chapel Hill faults there is but little Palestine sandstone in the Cave in Rock quadrangle, a mere capping of the hills both north and south of the Tribune road near the eastern boundary of the quadrangle.

South of the Chapel Hill fault the Palestine sandstone occupies a part or the whole of several fault blocks in the middle part of the Crayne rectangle. A considerable area of the formation is present in this part of the rectangle, to the south and west of the Midway School, and in the hills along the course of Butler Creek and some of its tributaries. A small patch of the sandstone is also present near the southeastern corner of the quadrangle where it overlies the Menard limestone which has been previously mentioned.

Between the Commodore and Crittenden Springs faults, in the Crittenden Springs and Sheridan rectangles, there are a number of fault blocks with Palestine sandstone. The sandstone east of the Commodore fault at the Bellman mine, one and one-fourth miles northeast of Glendale, is Palestine, and it extends to the northeast across Hurricane Creek, where it forms a conspicuous bluff for a short distance. The sandstone is present in two adjacent blocks at the place, the more eastern one having the Menard limestone exposed at the creek level. The hill lying southwest of Hurricane Creek, between Crittenden Spring and the Bellman mine, is capped with the Palestine sandstone, and exposures of the formation may be seen along the public highway between the two points. Along the road from Siloam School to Crittenden Springs the Palestine sandstone is present for much of the distance, the outcrops belonging in two different fault blocks.

In the Salem rectangle the Palestine sandstone is present south of Hardin Knob and a small area is also present north of the Knob. The formation outcrops west of the Salem-Tolu road on the boundary between Crittenden and Livingston Counties, and farther north it lies on both sides of Sandy Creek. It is also present in a rhomboidal fault block southeast of Hardin Knob, traversed by one of the tributaries of Coefield Fork of Deer Creek.

Lithologic Characters. The Palestine resembles the other thicker sandstones of the Chester Series in the Cave in Rock quadrangle, in texture and color. It is commonly yellow upon freshly broken surfaces, but the weathered surfaces may appear reddish, brown or gray. In most if not all sections, the lower beds of the formation are as massive as any of the Chester sandstones of the district, but the higher part of the formation becomes more thinly bedded, though it probably nowhere becomes so thinly bedded and shaly as the Tar Springs does in places.

Thickness. Where the thickness of the Palestine can be best estimated in the Cave in Rock quadrangle, the interval occupied by the formation seems to be about 60 feet, although in places it may be somewhat more than this, perhaps as much as 75 or 80 feet. These estimates agree well with the observations upon the formation elsewhere in western Kentucky and southern Illinois, where 60 feet seems to be the usual average thickness of the formation, with some variation both ways.

Stratigraphic Relations. The presence of an unconformity below the Palestine sandstone has already been suggested. At its summit the formation seems to pass without interruption into the overlying formation, at least there have been no observations in the Cave in Rock quadrangle which suggest any unconformity at this horizon, and this situation conforms with that elsewhere in the district occupied by the Chester formations.

Correlation. Like the other Chester formations in western Kentucky, the continuity of the Palestine sandstone has been established by tracing out the outcrops through the area between Caldwell County, Kentucky, and Randolph County, Illinois.

Clore, Degonia and Kinkaid Formations.

In the southern Illinois section of the Chester Series, the Palestine sandstone is succeeded by three formations, the Clore limestone, the Degonia sandstone and the Kinkaid limestone. The typical exposures of the Clore are in Randolph County, Illinois, the Degonia and Kinkaid both being typically developed in Jackson County, Illinois. In Jackson and Union Counties, Illinois, where the Degonia has its greatest development, the formation is a great bluff forming sandstone 100 feet or more in thickness, but as it is traced to the east it becomes much thinner and less massive. In Hardin County, Illinois, its thickness probably does not exceed 50 feet, and in places it may be less than this. The formation has been recognized in the Golconda quadrangle in Kentucky, and is sufficiently well developed there to be mapped as a distinct unit. The thinning continues to the east, however, and it has not been found to be practicable to map it in the Cave in Rock quadrangle, although a sandstone bed is present in places which is undoubtedly the Degonia. This situation brings the Clore and Kinkaid limestones nearly in contact, with only an obscure sandy layer separating them. Furthermore the Clore itself is thin and contains much shale, so that the beds immediately above the Palestine are commonly so situated that they are more or less obscured by talus accumulations, so that it has been impossible to map these formations as separate units in this quadrangle. The Clore horizon has been certainly recognized in places and it is believed to be a persistent member of the section throughout the district. Under these circumstances the interval between the summit of the Palestine sandstone and the base of the Pottsville has been treated as a single unit in the mapping, and the three formations will be considered together. By far the greater portion of the unit is the Kinkaid limestone which is a thick formation wherever it has not suffered extensive pre-Pottsville erosion.

Distribution. In their general distribution these formations are present throughout the Chester district of western Kentucky and southern Illinois, at least as far as from Caldwell County, Kentucky, to Randolph County, Illinois.

In the Cave in Rock quadrangle the Clore-Kinkaid limestones, shales and sandstones occupy a narrow, sinuous belt extending from a point near the middle of the northern boundary of the Weston rectangle to the southeastern corner of the same, and continuing for a short distance into the northeastern corner of the Marion rectangle. Farther south in the Marion rectangle, these formations occupy the entire distance between the Moore's Hill and Marion faults, at the eastern boundary of the quadrangle. In this area the formations are actually present in two distinct wedge-shaped fault blocks, whose points are adjacent to the Moore's Hill and Marion faults respectively, and about two and one-half miles from the east boundary of the quadrangle.

In the Crayne rectangle the Clore-Kinkaid beds outcrop both north and south of Pilot Knob, in the valleys of Black's Branch and Butler Creek, and the outcrop extends west to Midway School and east to the boundary of the quadrangle, occupying the greater portion of that part of the fault block bounded by the Chapel Hill, Midway School and fault No. 88, lying north of Butler Creek, except the high points which are capped with the Pottsville. In this area the true Clore is well exhibited in the road and stream bed one-half mile northeast of Pilot Knob. The limestone and shale which is so well exposed in the public road just south of Piney Fork Church is Kinkaid, and this outcrop extends eastward to the boundary of the quadrangle and westward to the Midway School fault. South of the Midway School fault a narrow, elongate fault block extending from the Midway School to the Lone Star School faults, occupies the valley tributary to Butler Creek just south of the Piney Fork road, and the creek valley itself for a short distance. A little over a half mile southeast of Midway School there is another small triangular fault block between the Midway School and Crayne faults in which the Kinkaid formation outcrops. The only other exposures of these beds in the eastern part of the quadrangle is in the extreme southeastern corner where the edge of a somewhat extensive area of outcrop to the south, extends over into this quadrangle.

In the Crittenden Springs and Sheridan rectangles the Clore-Kinkaid limestones outcrop in two fault blocks, but the outcrop in the two blocks is almost continuous. This outcrop begins east of the Commodore fault at Glen Dale School, extends north past the Commodore mine, then east and south to fault No. 54. At this fault, one-half mile north of Crittenden Springs, the outcrop is offset to the east and continues southwesterly along the west wall of Hurricane valley to the Siloam fault, and then swings west and northwest to the Commodore fault again. There are good exposures of the limestone at a number of localities along this belt of outcrop, one of them being along the Marion-Sheridan road, a little over a mile southeast of the latter place.

Farther to the southwest, in the Salem rectangle, these formations entirely surround Hardin Knob and continue more or less interruptedly in a southwest direction to the edge of the quadrangle, in the fault blocks lying between the Sandy Creek and Sheridan faults, occupying the lower ground where the hill tops are capped with Pottsville.

Lithologic Characters. The portions of the Clore-Kinkaid formations most commonly exposed to view are limestone beds, but along some stream channels and some roads crossing the outcrops, other sorts of strata may be seen, mainly shales, but in some portions of the formation thin sandstone beds also.

The limestone strata of the formation exhibit much variety in character. Most of the beds are gray or bluish gray in color, but in places they are distinctly yellow, The harder beds are compact and close textured, breaking with a splintery fracture, and in every way resembling lithologically the more usual type of limestone present in the Menard formation. As in the older formation such beds are commonly in layers of one foot, more or less, in thickness, with somewhat hummocky bedding planes and with shale partings. Limited outcrops of the formation of this sort, which are commonly if not always in the Kinkaid portion, could not be distinguished from similar outcrops of the Menard limestone. Other limestone beds in the formation are more or less argillaceous in character and these grade into calcareous shales. The yellow beds which are present in places are commonly more or less argillaceous, although in some places they seem to be dolomitic.

The shale beds on the whole are probably greater in mass than the limestones, the formation being much more shaly than the Menard, but less shaly than the Golconda in this quadrangle. The shales vary greatly in character. Some are highly calcareous and others are almost wholly argillaceous. The colors are gray, yellow, black, red and olive green. The association of red and olive green shales is rather characteristic of the formation.

The sandstone beds are less extensive than either the limestone or the shale. One bed towards the base of the series, probably ten or fifteen feet thick, seems to be persistent and doubtless represents the thinned out edge of the Degonia sandstone. Higher up there are one or two other thin beds which also may be persistent. The sandstones are thinly bedded, yellow to brown or green yellow in color, and in places are more or less carbonaceous. They are commonly ripple marked and otherwise branded with shallow water markings.

Nowhere associated with the Kinkaid limestone in this quadrangle are there any such conspicuous chert beds as those which are present in some parts of the Golconda quadrangle, and in parts of Hardin and Pope Counties, Illinois, neither have the irregular chert masses been observed which occur locally at the top of the formation in the Princeton quadrangle.

Thickness. The thickness of the entire Clore-Kinkaid limestone unit in the Cave in Rock quadrangle varies considerably. This variation is due to the difference in the amount of pre-Pottsville erosion, so that the great difference in thickness must come in the Kinkaid limestone portion. The Clore horizon as well as the Degonia sandstone portion are probably somewhat uniform in thickness although the exposures are not such as to permit any accurate estimates, but probably neither of these members exceed twenty or twenty-five feet, but the Clore is probably thicker than the Degonia. The whole series of beds is apparently thin in the northeastern portion of the quadrangle, where in places there cannot be more than 50 or 60 feet between the top of the Palestine and the base of the Pottsville. The greatest thickness is exhibited in the outcrops in the Salem rectangle about Hardin Knob and to the southwest from there, where the thickness exceeds 150 feet in places, perhaps being as much as 175 feet.

Stratigraphic Relations. The Clore probably lies conformably upon the underlying Palestine sandstone, and there is no reason to believe that there is any interruption in the sedimentary record through the Clore and Degonia and Kinkaid in this area, although there may be stratigraphic breaks elsewhere. At the top of the Kinkaid, however, there is a profound unconformity between this formation and the Pottsville sandstones.

Paleontology. No extensive fossil collections have been made from the Kinkaid limestone in this quadrangle. However a collection from the Clore horizon has been secured from a point one-half mile northeast of Pilot Knob, and the following species have been identified.

FAUNA OF CLORE LIMESTONE FROM NORTHEAST OF PILOT KNOB.

Spirorbis sp.
Cornulites sp.
Archaeocidaris sp. (plate)
Batostomella nitidula Ulrich.
Stenopora cestriensis Ulrich.
Lioclema araneum Ulrich.
Fenestella tenax Ulrich.
F. serratula Ulrich.
Archimedes terebriformis Ulrich.
Polypora sp.
Septopora subquadrans Ulrich.
Rhombopora sp.
Crania sp.
Orthotetes kaskaskiensis (McChesney).
Productus ovatus Hall.
P. n. sp.
Camarophoria explanata (McChesney).
Spiriferina sp.
Spirifer increbescens.
Eumetria vera Hall.
Composita subquadrata Hall.
Aviculopecten sp.

The platy limestone beds with surfaces bearing numerous examples of the bryozoan Batostomella is a characteristic feature of the Clore limestone wherever it has been studied, and this occurrence in the Cave in Rock quadrangle shows the same characteristic.

CHAPTER IV

STRATIGRAPHIC GEOLOGY. PENNSYLVANIAN.

Introductory Statement.

As in the adjoining areas, all of the Pennsylvanian strata in the Cave in Rock quadrangle are of Pottsville age, and only the Caseyville formation of the Pottsville is present. Although these beds are the oldest of the Pennsylvanian System in this part of Kentucky, there are much older post-Mississippian formations elsewhere, the age of the Caseyville being Upper Pottsville as is shown by the fossil flora which is preserved in some of the beds. While the Middle and Lower Pottsville strata were being deposited elsewhere, this portion of the continent was an area of dry land where no accumulation of sediments was possible, and where the older Chester surface was being subjected to erosion.

Caseyville Formation.

Name. The typical exposures of this formation are at Caseyville on the Ohio River, a few miles north of the boundary of the Cave in Rock quadrangle.

Distribution. The Caseyville formation is widely distributed in this portion of western Kentucky and the adjacent portion of Illinois. In the Cave in Rock quadrangle the largest area occupied by the formation is in the northeastern portion of the quadrangle, in the Weston rectangle, and the Henderson road crosses the formation from a point less than one-half mile north of the Baker School to where the road leaves the quadrangle. The width of the Caseyville outcrop along the north boundary of the quadrangle is about two and one-half miles from the northeast corner. This area continues to the east and north into adjacent quadrangles for a long distance, being a part of the unbroken western Kentucky Pennsylvanian which extends to Hancock County, more than 75 miles.

The remaining occurrences of the Caseyville formation in the Cave in Rock quadrangle are outliers which cap the most deeply downdropped fault blocks. One such area is exhibited at Pilot Knob, a mile northwest of Piney Fork Church. The greatest thickness of the formation in this outlier is at Pilot Knob, but it occupies the high ground for nearly two miles west of this knob, south of the Chapel Hill fault. The high hill about one mile a little north of east from Pilot Knob, which continues eastward into the Providence quadrangle, is also capped by the Caseyville. In this same fault block a small elliptical hill rising to 660 feet elevation, is strewn with fragments of Caseyville and doubtless has a capping of the formation beneath the surficial deposits.

In another fault block the Caseyville outcrops at Piney Fork Church, and along the road for three-fourths of a mile to the west, but this area is much less extensive than that from Pilot Knob.

The largest one of the outlying areas of Caseyville is situated to the south and east of Glendale. This area is more than a mile in width and more than two miles in length, extending northeast from the Marion-Sheridan road, a mile southeast of the latter place.

Another prominent Caseyville outlier is Hardin Knob in the northern part of the Salem rectangle, and in several fault blocks to the west and southwest of the Knob, the same formation caps the higher hills lying between Flat Lick Creek and the Corn School. In the same general region, but a little farther south, the hill at the Crittenden-Livingston County boundary, at the west edge of the quadrangle, is capped by the Caseyville, this area extending for a considerable distance to the southwest into the Golconda quadrangle.

Lithologic Characters. The Caseyville is for the most part a sandstone formation, but it includes also some sandy shales and even clay shales, and locally a thin bed of coal. In places the sandstone is conglomeratic, the included pebbles being smoothly rounded white quartz. Not infrequently the presence of the formation may be detected by the masses of the characteristic conglomerate which are washed down along some of the water courses which originate in or cross the Caseyville outcrops. In some places the formation is quite free from conglomerate, that being the case around Pilot Knob, but at this locality certain beds with fossil ferns show the formation to be

Caseyville with no uncertainty, and a mile or less to the west conglomerate beds do occur.

Where no conglomerate is present in the Caseyville the sandstone in places resembles some of the Chester sandstones, and without a recognition of the stratigraphic relations it is locally difficult to recognize the formation. Most of the sandstones, however, are coarser than is common in the Chester, and they are likely to exhibit more red iron staining, the iron in places occurring as more or less contorted plates or laminae which stand out in relief upon weathered surfaces.

In the ravine extending to the east from Glenwood School, the non-conglomeratic sandstone beds of the Caseyville formation are well exhibited, and near the head of the ravine a thin bed of coal is included in the series. At some earlier time this coal bed has been mined for local consumption, but the drifts have been closed for a long time so that the actual exposures of the coal cannot be studied at this time. It is too thin to be profitable for mining, even for local use.

Thickness. The total thickness of the Caseyville in the Cave in Rock quadrangle cannot be accurately determined. In the northeastern part of the quadrangle there must be more than 200 feet of strata, and the thickness in the outlying areas varies from 20 to 160 feet. The total thickness of the Caseyville is probably about 400 feet where the entire formation is preserved.

Stratigraphic Relations. The unconformity at the base of the Caseyville is the greatest stratigraphic break in the entire exposed series of hard rock formations in the quadrangle, and is the same unconformity that is widely present throughout the interior of the continent, separating the Mississippian from the Pennsylvanian. Wherever they occur in the quadrangle, the Pottsville rocks are the highest in the section, being succeeded by the unconsolidated, surficial mantle rocks.

Paleontology. No invertebrate fossils have been observed in any of the Caseyville rocks of this portion of Kentucky, but fossil plants are not infrequently met with. In places there are impressions of the trunks of Lepidodendron, one of the ancient carboniferous trees, and in some beds beautifully preserved fossil ferns may be found.

CHAPTER V

STRATIGRAPHIC GEOLOGY. CRETACEOUS.

Distribution. Throughout much of the Mississippi embayment, extending as far north as southern Illinois, there are widespread deposits of more or less unconsolidated sands and clays often referred to as the "embayment deposits," which are probably Cretaceous in age. Heretofore these deposits have not been mapped in Kentucky north or east of the Tennessee River. Their occurance was indicated in the general region by Jillson in 1920[1].

During the prosecution of the field work in the Cave in Rock quadrangle, two localities have been discovered where sands and clays of the "embayment deposits" are present, and a more thorough search of the northwestern portion of the quadrangle will doubtless bring to light other occurrences. Both of the localities which have been met with are in the valley of Caney Fork. The first one is on the north side of the creek a little less than three and three-fourths miles from the western boundary of the quadrangle, nearly two and one-fourth miles almost due south from Colan School. The second locality is east of Caney Fork, directly back of Hurricane Church, about two and one-half miles from the first locality. It is not unlikely that the whole valley side, perhaps both sides, are occupied by these deposits, and that they occur in other of the valleys tributary to the Ohio River, but where the hill slopes are covered with timber and with more recent surficial deposits, they are effectually obscured. However, because of the limitations of available time, no thorough search has been made for these deposits, and other exposures as good as the ones which have been observed, may exist.

In early years a considerable amount of iron ore was produced in the region adjacent to where these exposures of the embayment beds have been observed, and at one time an iron furnace was in operation near Hurricane Church. There is reason to believe that the iron was secured from these embayment deposits. The old pits from which the iron was dug are now covered and are more or less overgrown with underbrush, but they seem to be associated with these sands.

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[1] Trans. Ky. Acad. Sc. 201, pp. 81-83, 1920-1924.

In the first of the localities which have been mentioned the elevation of the sands is about 460 feet above sea level, but back of Hurricane Church the elevation is below 400 feet.

Lithologic Character. The best expression of these beds is at the first mentioned locality. At this place there is a bank of sand 15 to 20 feet high. It is somewhat variable in color, from nearly white or light yellow, to deep orange. Most of it is unconsolidated, but there are masses intercalated in the beds which are fairly well cemented, but these hard beds do not constitute distinct horizontal strata. Associated with the sand there are some thin, irregular bands of white clay, only a fraction of an inch in thickness, which are an inconspicuous element in the formation as a whole. On the hillside near the exposure there is a large mass of iron conglomerate which doubtless was derived from these beds, and is perhaps a sample of the type of iron ore which was formerly smelted in the furnace at Hurricane. A quarter of a mile northwest of the exposure described, a number of small prospect holes have been excavated from which yellow, red and purple sand has been thrown, which is doubtless from these same "embayment deposits."

East of the Tolu road, which is half a mile northeast of the main exposure of these beds, there are scattered masses of sandstone resembling in some respects some of the Chester sandstones, but they are far removed from any of the Chester formations and doubtless have been derived from some of the "embayment deposits." Statements are made by persons living in this vicinity concerning a deposit of white kaolin. None of the material was seen in connection with our field work, nor was the exact locality of the deposit learned, it now being hidden by surficial wash, but the descriptions given of this clay suggest that it may be associated with the formation under consideration.

At the second locality where these sands have been observed, back of Hurricane Church, a number of pits were dug some years ago, in prospecting for mineral. About these prospect holes the same character of sand is present as that which has been described from the locality farther southeast. In neither locality can any definite lines be drawn outlining the extent of the formation, because of the growth of timber and underbrush, and because of the surficial wash, but it is not improbable that the deposits may be essentially continuous along the valley of Caney Fork.

Stratigraphic Relations. The beds of course lie unconformably upon the underlying hard rocks which are the St. Louis limestone. Being situated as they are on the valley sides, they show that the topography of the district had already assumed much of its present configuration before their accumulation. It is not improbable that some of the valleys were more or less completely filled originally, with these sands and clays, and that they have been re-excavated in more recent time through the washing out of these nonresistant materials, only the remnants now remaining upon the valley sides.

The hill top or Lafayette gravels which rest unconformably upon these sands and clays in some southern Illinois localities, and which also locally lie directly upon the hard rock surface in the same general region, have not been observed in this quadrangle, although typical deposits of the gravels are present in the Princeton quadrangle.[1] At one locality a few rounded chert pebbles, similar to those of the Lafayette gravel, have been observed mixed with the sand, but no definite bed of gravel overlying the sands has been seen.

Correlation. The character of these sands is such as to render it practically certain that they are to be considered as an eastward extension of similar "embayment deposits" which are conspicuously developed in the counties of Illinois bordering the Ohio River from Pope County, west, and in the adjacent portion of Kentucky. Nowhere in this whole district have they been found to be fossiliferous, but on being traced to the south they seem to be continuous with sediments which are certainly Cretaceous in age.

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[1] Ky. Geol. Surv., ser. 6, vol. 10, pp. 93-95 (1923).

CHAPTER VI

IGNEOUS ROCKS.

All of the rocks of the earth's crust are either sedimentary or igneous in origin. The sedimentary rocks have been formed by the deposition in layers of various sorts of materials which have been held in suspension, and have been permitted to settle and accumulate in blanket-like layers. By far the most of the sedimentary rocks are made up of particles which have been suspended in either marine or fresh water, but a special type of them have been held in suspension in the air and have been accumulated as aeolian or wind deposits.

The igneous rocks have all, at some time, been in a molten condition, and lie in positions very different from the sedimentary rocks. The molten rock, or lava, either has been extruded to the surface in the manner exhibited by the active volcanoes which are in existence upon the earth today, or it has been intruded into and between the layers of sedimentary and other rocks of which the crust is formed, without actually breaking through to the surface. In the case of such intrusions there have been, in most cases, minor stringers, dikes or sills, which have penetrated farther out into the enclosing sediments, along preexisting cracks or joints, or along openings produced by the molten rock itself, and in many places the erosion of the rocks of the surface has been carried far enough to disclose these dikes, while the main mass from which they have been pushed out remains deeply buried.

In their areal extent, unless the rocks are of the extrusive sort which have flowed out over the surface from the vent of some volcano, or unless the processes of erosion have uncovered the main intruded mass, the igneous rocks of a region commonly occupy only a minor portion of the surface, indeed in many, perhaps most localities there are no ingeous rocks at all.

Igneous dikes commonly occur in more or less vertical position, and may vary in thickness from a few inches to many feet. In some regions where dikes occur the rock of which they are composed is more resistant than the sedimentary beds which they have penetrated, and in such situations the dikes stand out as conspicuous topographic features. In other places the dike rock is easily decomposed and is less resistant than the enclosing sediments, in which case the dikes are hidden by the accumulation of residual material and are commonly exposed only by accident.

The presence of igneous dikes in western Kentucky and southeastern Illinois has long been known, and their locations have been indicated upon various geological maps. In all three of the quadrangles which recently have been mapped in detail, dikes have been recognized but it is in the Cave in Rock quadrangle that they are the most numerous. All of these dikes are similar in character and are composed of a dark, basic rock known as peridotite. Those which are known vary from a few inches to perhaps four or five feet in width. The rock of which they are composed is commonly nearly black or dark greenish in color, mostly finely crystalline, with occasional bits or small masses of black mica. The dike rock is more easily decomposed than most of the sedimentary rocks by which it is inclosed, and consequently the dikes are commonly more or less obscure. Almost the only natural exposure of the undecomposed rock in the quadrangle, is along Clay Lick Creek, three miles southwest of Marion, where a number of thin dikes may be seen crossing the solid limestone bed of the creek. Where the dikes have been deeply decomposed, the residual surface material is somewhat different from that of the sedimentary rocks, although in many places the residuum of the dike rock and the inclosing sediments is so mixed that the dike may not be suspected. The characteristic dike residuum, more or less chocolate brown or reddish brown in color, with flakes of mica, is commonly called "mica dirt" by the local prospectors, and wherever "mica dirt" has been detected a prospector's hole may be looked for. In fact most of the occurrences of dikes in the whole quadrangle are to be found in such excavations.

Nearly twenty actual exposures of dike rock have been observed during the progress of the work in the Cave in Rock quadrangle, and a number of others have been reported which have not been seen. In no case is there an extended exposure of a dike along the surface of the ground, but in a number of places a series of exposures, some of them a mile or more apart, are so situated in line as to suggest the presence of dikes continuing for several miles at least. Perhaps the best exhibition of such a situation is in the alignment of the dikes exposed in the bed of Clay Lick Creek, the Old Jim dike, and a dike at Glendale, a total distance of more than five miles. A dike near View is perhaps in alignment with a dike exposed in a prospect hole about one mile southeast of Levias. At the Crystal Fluorspar mine, southwest of Sheridan, a dike has been penetrated which lines up with a number of exposures stretching over a distance or more than two miles. It is altogether probable that numerous other dike exposures may be met with in the future and some of them may be in alignment with lines already established, or with exposures which now seem to be isolated.

By far the best exhibition of igneous rock in the quadrangle is at the Crystal Fluorspar mine, where a shaft has been sunk upon the dike and along which a number of drifts have been carried. At this place one of the cross faults between the Sheridan and Big Four faults coincides with the dike, and the mineralization lies alongside and in the dike rock. The coincidence of fault and dike at this place is probably accidental, for a dike exposure in alignment with those along this fault has been observed, one mile southeast of the Sheridan fault, where there is no faulting in line with the dike. This dike is about four feet in width and is much broken by the faulting, with slickensided surfaces within the dike rock, and having fractures healed with mineral material.

A sill differs from a dike in having a horizontal position. It is really an intrusion between more or less horizontal layers of rock, and commonly must connect somewhere with a dike which leads to the main igneous mass. The best exhibition of a sill in the Cave in Rock quadrangle, is present in the northwest valley wall of Clay Lick Creek, a little less than one mile northeast of Cisco School, only a short distance from the dike exposures in the creek bed. This igneous rock is of the same character as the dikes and is about 15 feet in thickness, lying between beds of the Tar Springs formation.

All of the evidence presented by the igneous rocks of the district suggests that an extended area in western Kentucky and southern Illinois is underlain by an igneous intrusion from which the dikes have penetrated upward into the covering sediments, some of these dikes being now exhibited at the surface by reason of the erosion of the overlying sediments. There is no present means of determining the depth at which such an intrusion exists, but it is believed that this intrusion, the extensive faulting of the district, and the mineral deposits are phenomena which are intimately related.

CHAPTER VII

STRUCTURAL GEOLOGY.

INTRODUCTORY STATEMENT.

The fault structure in the Cave in Rock quadrangle corresponds in general type with the structure exhibited in the Golconda and Princeton quadrangles, and with that in Hardin and Pope Counties, Illinois. A sufficiently large area has now been covered by detailed mapping to bring out certain features which are not suggested through observations in a small area. The fault habit throughout the entire district is the same. The larger and more continuous faults through much of the district, have a northeast-southwest direction, but toward the west a more northerly trend is observable, the last fault in the district, in Johnson County, Illinois, being essentially north-south in trend, while to the southeast the direction becomes more east-westerly. This more easterly direction of the faults is shown to some extent in the southeastern portion of the Cave in Rock quadrangle, but it is more conspicuously exhibited in the Princeton quadrangle.

The directions assumed by these faults suggests possibly that the portion of the district which has been mapped constitutes the northeastern quadrant of a more or less circular area in which there is a radial arrangement of the major faults, the center of the disturbance being to the south and west of the Cave in Rock quadrangle. The absence of any faulting in the western portion of Johnson County, Illinois, however, where northwesterly directed faults might be looked for to make complete the radial fault pattern, indicates that the district as a whole has not been deformed in an entirely symmetrical manner.

The continuation of this fault system to the south and southwest is hidden by the accumulation of the Mississippi embayment deposits of Cretaceous and Tertiary age, but it will be observed that a projection to the southwest of the major lines of faulting in Hardin County, Illinois, and in western Kentucky, essentially coincides with the western border of the Mississippi embayment deposits across Arkansas and Louisiana. If these faults do continue in that direction beneath the younger sediments, then this embayment may be considered as of structural origin, being in fact a great downdropped block, rather than an erosional embayment as has been assumed commonly. Furthermore, the direction of this belt of deformation and its possible extension, is essentially parallel with the Appalachian structures farther to the east.

The longer faults in the district occur in groups which are more or less parallel in direction, however this parallelism is only approximate, for the faults intersect, generally at low angles, and there are innumerable short cross faults lying in every direction. The fault intersections form wedge-shaped blocks which are conspicuous throughout the fault pattern of the entire district. The points of the wedges are commonly broken by one or more cross faults, in some cases allowing the point of the wedge to drop deeper than the wider portion of the block, although more rarely the severed point remains higher and the broader portion of the wedge drops down. In those cases where there are several cross faults towards the end of a wedge-shaped block, their dislocations represent a successive downdropping in either one direction or the other, the more common relation being with the greatest amount of downdrop at the point of the wedge. In places there are series of cross faults joining sub-parallel longer faults at a distance from any wedge-shaped termination and in those cases also the dislocation is progressively downward in one direction or the other, the successive blocks being a series of steps. In only rare cases do any of the cross faults continue beyond the limiting, sub-parallel faults at either side. In certain situations there are areas, commonly subtriangular in outline, and in reality terminal portions of larger wedge-shaped blocks, which are more than usually broken up, forming veritable fault complexes. Such areas are likely to be more richly mineralized than common, judging from the development work which has already been accomplished.

A particularly characteristic structure habit of the district is the presence of downdropped belts, varying in width from one to three miles, having a northeast-southwest direction. Two such belts cross the Cave in Rock quadrangle. One of these extends from the Ohio River at Fords Ferry and Weston, to the western border of the quadrangle where it lies between two and five miles from the southwestern corner. This belt continues across the southeastern portion of the Golconda quadrangle and on to the southwest in the, as yet, unmapped area. The youngest formations in this belt are Pottsville, and where the belt has dropped the deepest the bounding formations are St. Louis and Ste. Genevieve limestones. In the vicinity of Glendale this belt bends slightly to a more southwesterly direction. The entire belt is most complexly fractured, and along its borders there are some of the most productive mining properties of the district.

THE GOLCONDA ESCARPMENT
This striking physical feature is shown in profile, looking east from the schoolhouse in Salem to Fairview Point.

The second of the downdropped belts enters the quadrangle from the east between Repton and the Tribune road out of Marion, its width being a little less than one and one-half miles. It crosses the quadrangle through Marion with a slightly arcuate course, in a southwest direction, crossing the southern boundary in the eastern part of the Salem rectangle. This belt maintains a nearly uniform width, but is much less complexly faulted than the first one mentioned, but like the belt previously described, rich mineral deposits have been discovered along its margins, especially in the more southern portion of its course. This belt, at least in the portion mapped, does not include formations as young as the Pottsville, the succession of beds from its southern extremity to where it leaves the quadrangle south of

Repton being from the Renault to the Kinkaid formations of the Chester Series.

Another similar downdropped belt crosses Hardin County, Illinois, through Rosiclare, and continues across the western portion of the Golconda quadrangle in Kentucky, again crossing the Ohio River into Illinois at the southwestern corner of that quadrangle. Still another belt of the same sort, but less complexly faulted, crosses Pope County, Illinois.

In order to more easily refer to these downdropped belts, the first one mentioned as crossing the Cave in Rock quadrangle may be designated as the Glendale belt, from Glendale School which is situated within the limits of the belt at about its midway point in the quadrangle. The second one mentioned may be called the Marion belt since nearly the whole of the city of Marion is included within its boundaries. The belt crossing Hardin County, Illinois, and the Golconda quadrangle may be called the Rosiclare belt. The Glendale and Rosiclare belts are much more nearly alike in their structural characters, the Marion belt being much simpler in all respects than either of the others.

In the Kentucky portion of the Cave in Rock quadrangle 125 distinct faults have been indicated upon the map, the dislocations varying from fifty feet or less to nearly or quite two thousand feet. Undoubtedly there are other faults present, perhaps many others, with minor dislocations, which have not been detected beneath the thick covering of superficial materials. Especially in the northwestern portion of the quadrangle, where the St. Louis limestone is the surface formation and where rock outcrops are not common, many other faults, especially cross faults, may be expected.

All of these faults are of the normal or tensional type, and have been formed by the stretching of this segment of the earth's crust. In seeking a cause for the tensional stresses which have produced all of these fault fractures, the numerous igneous dikes in the district suggest an explanation. At the time of their introduction into the crust, all of these dikes were more or less liquid, molten rock which was injected with tremendous force from below, where they must have been connected with a great body of similar molten rock. The depth at which such a body of igneous rock may exist cannot be determined at the present time, because no excavations and no deep well drillings have been carried far enough to penetrate it, but the presence of such a rock mass underlying the whole area in which the igneous dikes are known, may be safely assumed, and the known outcrops of dikes extend at least as far as from Caldwell County, Kentucky, to Pope County, Illinois. It is not improbable that numerous unsuspected dikes are covered by surficial materials, and there may be others beyond the limits of their present known occurrence. The existence of numerous faults beyond the known limits of the dikes at least suggests the greater extent of the buried igneous rock.

The supposed deeply buried mass of igneous rock must have been forced into its present position from the outside, perhaps through the agency of the folding of the Appalachian Mountains to the east, and in coming into its present position it had necessarily to bow up the overlying sedimentary beds. Such bowing up stretched the crust, and because of its rigidity and lack of elasticity the strata subjected to the strains fractured along many lines. Such fractures would not be perfectly vertical, and their inclinations would be in different directions so that in vertical cross-sections the blocks would present wedge-shaped outlines. With the pushing up of the molten rock from below, those blocks whose thinner edges were directed upward were pushed up between blocks whose thinner edges were directed downward, and such a wedging together took up the slack in the lengthening segment of the upbowed crust. After the completion of this process the intruded mass of igneous material, lying beneath several thousands of feet of overlying sediments which had been bowed up, was subjected to the enormous weight of this overburden. The cooling of the igneous mass was slow, and was accompanied by contraction, and for a long time the great pressure upon the hot, more or less liquid or plastic material, tended to squeeze it out laterally and so increase the diameter of the upbowed segment and reduce its elevation in the central portion. These processes caused a further adjustment of fault blocks, either along the same fractures formed by the upbowing of the segment, or along newly formed fractures, the movements at this time being a slipping back of the wedge-shaped blocks.

The final result of all the deformative movements of the region, and the subsequent erosion of the surface, is what exists today, and the geologist must draw his conclusions from close observation and study of these results, and attempt as nearly as possible to determine the sequence of events which have produced the observed phenomena. Among other things it is important to determine, if possible, when all of these deformative movements took place. The fact that the Pottsville sediments are involved in the deformation, and have been brought into fault contact with older sediments, shows conclusively that the fracturing occurred later than Pottsville time. Some of the faults in the district extend eastward into the higher Pennsylvanian formations, which shows that the faulting occurred subsequent to the time of deposition of the younger Pennsylvanian sediments in western Kentucky. It is more difficult to establish a time limit for the faulting in the other direction, for there is no sedimentary record in the faulted district from the Pennsylvanian to the sediments forming the "embayment deposits" which are probably Cretaceous in age. It is known that in some places, certainly, the faults pass beneath these "embayment deposits," with no disturbance of the younger beds recognizable, so that the faulting must have occurred after the Pennsylvanian and before the Cretaceous. If the deep seated igneous intrusion is connected in any manner with the Appalachian deformation, then this faulting in Kentucky must have occurred at the time of the Appalachian folding, which is known to have taken place at the close of the Paleozoic time. In all probability the western Kentucky deformation was contemporaneous with the Appalachian disturbances. However, all of the readjustments were not accomplished at once, and minor movements have been in progress, probably, even down to the present time. Scarcely a year passes without some report of one or more slight earth tremors in this general region of the Ohio Valley. During 1923 no less than three such earthquakes have been reported in the public press during October and November. The more severe New Madrid earthquake of 1812 may well have been the result of a slip along one of these faults in the Ohio Valley. In the fluorspar mines of the district slickensided surfaces are not infrequently met with within the ore bodies themselves, showing that movement has taken place long after the major dislocations had been accomplished.

DESCRIPTION OF FAULTS.

The several faults in the Cave in Rock quadrangle have been designated by serial numbers, as was done in both the Golconda and Princeton quadrangle reports. In each quadrangle the numbering has been begun with 1 and has been carried as far as necessary. In order to distinguish the faults of the several quadrangles, whenever such procedure is necessary, the number will be preceded by the initial letter of the quadrangle, viz., G6 signifies fault No. 6 in the Golconda quadrangle, P6 and C6 being faults in the Princeton and Cave in Rock quadrangles respectively. Some of the faults in this quadrangle continue into the Golconda quadrangle to the west, and in such cases they have different numbers on the two sides of the boundary between the quadrangles, but the letter preceding the number will always indicate which fault is referred to. Some of the more important faults in the quadrangle have been given names as well as numbers, and therefore may be referred to either by name or number.

The numbers used to designate the faults are those shown upon the "Map of the Structural Geology (Fault Pattern) of the Golconda and Cave in Rock Quadrangles," prepared by the writer of this report and published by the Kentucky Geological Survey in 1925. Since the original work on the geology of the quadrangle was accomplished, some additional field work has established the existence of a number of shorter faults in some of the more complexly faulted areas, which are now shown on the geological map for the first time. These faults account for the difference in the number of faults now recognized (125), and the number shown upon the earlier map (107).

Fault No. 1. This fault is a continuation of G18 from the southwest. For much of its distance in both the Golconda and Cave in Rock quadrangles it has St. Louis limestone upon each side, so that in the absence of good exposures and with the deep covering of residuum, it is practically a blind fault. Its presence in the southwestern part of its course in the Golconda quadrangle is clearly enough indicated with the downthrow on the northwest side, and its direction is well shown. In the Cave in Rock quadrangle there is an outcrop of Chester sandstone in the public highway about half way between Tolu and Hurricane Church, whose presence must be due to faulting, and the projection of the known portion of G18 brings it alongside this sandstone outcrop. This is perhaps slender evidence for placing the fault upon the map, but it is believed to exist approximately as shown.

Fault No. 2. This fault is essentially a continuation of C1 with a slight change in direction. The sandstone outcrop in the road between Tolu and Hurricane Church is apparently completely surrounded by St. Louis limestone, and its presence can only be explained by postulating faults on all sides. From the general fault habit of the district it may be assumed to be a triangular block which has dropped downward at the point of a wedge. In the Ohio River bank two miles above Weston almost at the edge of the quadrangle a fault brings the Pottsville sandstones on the north down against the Chester formations. This fault has been recognized and mapped by Wallace Lee[1] in its extension across the Shawneetown quadrangle. The direction of this fault in the river bluff, when projected, carries it to the sandstone outcrop between Tolu and Hurricane Church, which has been mentioned, and it is assumed to be present along this course. The presence of a fault in approximately this position is further suggested by the differences in the geological section on the two sides of the Ohio River in this quadrangle.[2] Further field observations between Tolu and Fords Ferry may bring out further confirmatory evidence for the location of the fault, but the fact that the St. Louis limestone is present on both sides makes its detection a matter of difficulty.

Fault No. 3. This is a very short cross fault in the wedge-shaped area at the intersection of faults 1 and 2, and has been introduced to bound the sandstone outcrop at that place on its third side. Such a fault must be present, but its actual position cannot be certainly established from the rock exposures available for observation.

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[1] Ky. Geol. Surv., Geol. of Shawneetown Quad. in Ky., p. 53 and map (1916).

[2] See Geol. Map of Hardin Co., Ill., Ill. State Geol. Surv., Bull. No. 41, (1920).

Fault No. 4 (Lola Fault). This is another blind fault with the St. Louis limestone on both sides, and is a continuation of G30. The presence of the fault is well established southwest of Lola in the Golconda quadrangle, where the Ste. Genevieve limestone on the northwest side is faulted against the lower Chester sandstones and limestones. One and one-half miles southwest of Lola the Bonanza mine is located on this structure. Evidences of the continuation of the fault as far as Lola are good, for fluorspar deposits have been opened upon it by the roadside in the town. To the northeast it is hidden, first in the Ste. Genevieve limestone, and farther along in the St. Louis limestone. However, about a mile east of Irma, in the Cave in Rock quadrangle, a body of fluorspar has been opened at the Sullinger mine, which is exactly in line with the projection of the fault through Lola, and it is believed that it is continuous to the point of its intersection with fault No. 2 near the Ohio River.

Fault No. 5. This is still another of the obscure faults through the St. Louis limestone area, and is a continuation of G42. In the Golconda quadrangle the fault is easily enough recognized just east of Canada Bridge, one and one-half miles southeast of Lola, and for nearly four miles its presence is well established by the different formations on the two sides, but about a mile northeast of Canada Bridge it is lost in the Ste. Genevieve and St. Louis limestones. For more than ten miles to the northeast there is little or nothing to indicate the presence of the fault, but a little less than one-half mile southeast of Hebron School a prospect mine has been opened on the Spring property which is believed to be upon this fault. Less than one-fourth mile northwest of Hebron School is another mining prospect which shows fluorspar and barite, and a quartzite outcrop may be seen by the side of a private road leading a little north of west, a mile and one-quarter southwest of Fords Ferry, both of which give additional evidence of this fault.

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Fault No. 6 (Commodore Fault). This is a well defined fault which can be traced from a point near the Ohio River for about thirteen miles to the southwest, its direction varying but little from north 20° to north 25° east. The Commodore mine near Glendale is located upon this fault near the middle point of its course, and the name of this mine has been selected to designate the fault. The fault is known to be extensively mineralized. A part of the operations at the Beard mines are associated with this structure, and other mines upon it are the Bellman mine, the Commodore, the Hickory Cane, the Glendale and the KK mines. Besides these, numerous other prospect holes have been sunk along the same line.

This fault is easily recognized through its entire length because of the differences in the formations on the two sides. For more than one-half of its length, except for a short distance near Fords Ferry close to the river, from just east of Sheridan to the Ohio River the St. Louis limestone lies west of the fault, and various other formations, Ste. Genevieve, Chester and Pottsville, are present on the east. Southwestward from the point east of Sheridan, the fault continues to the vicinity of Crosson Cave, through formations of Chester age for the most part, though it terminates in the Ste. Genevieve limestone. The amount of dislocation along the fault varies greatly and irregularly because of the much broken up condition of the strata lying to the east of it, and upon both sides in the southern portion of its course. The maximum dislocation is between Glendale and the point east of Sheridan where the St. Louis limestone is faulted against Pottsville sandstone. The whole of the Chester Series and all of the Ste. Genevieve limestone are faulted out, also a considerable portion of the St. Louis limestone, and perhaps 100 feet of Pottsville. The total dislocation must approximate 2,000 feet for this portion of the fault, which is the maximum for the whole quadrangle. At its extreme southern end the fault dies out to nothing so that the whole dislocation varies from nothing to about 2,000 feet. The amount of dislocation is also reduced to the north where the fault probably joins fault No. 5 a short distance southwest of where that one joins No. 2.

The northern half of the Commodore fault constitutes the western boundary of the Glendale faulted belt, but farther to the southwest this boundary switches to the Sheridan Fault.

Fault No. 7. The exact position of fault No. 7 has not been determined, but the presence of such a cross fault, somewhere near the place indicated, joining faults 5 and 6, and cutting off the point of the wedge between them, is probable. The greater portion of the block between faults 5 and 6 is St. Louis limestone, but at its northern extremity there is a hill capped by the Bethel sandstone, and the situation is such that it is improbable that the whole of the Renault and Ste. Genevieve, and a portion of the St. Louis, dip beneath the sandstone. Furthermore, from a knowledge of the district, as a whole, it is known that the terminal portions of such wedge-shaped fault blocks are commonly broken off and downdropped relative to the surrounding blocks.

Fault No. 8 (Sheridan Fault). The Sheridan fault is subparallel with faults 1, 4, and 5, its direction being between north 40° and north 50° east. To the southeast it continues as G54. Its length within the Cave in Rock quadrangle is about six and one-half miles, and it continues for one and one-half miles farther in the Golconda quadrangle. It diverges from the Commodore fault with an angle of about 22°, at a point between the Commodore and the Bellman mines, and crosses the road to Irma just outside of Sheridan. The fault is obscure in its northeastern half because of the presence of the St. Louis limestone on each side of it, although at the road crossing just north of Sheridan the existence of the fault is indicated by the presence of sandstones which have slipped down along the fracture. To the southwest it is more easily recognized because of the difference in the formations on the two sides. The fault is known to be mineralized at a number of points, the most productive mines along it being the Miller and the Corn mines.

Faults Nos. 9, 10, 11 and 12. These four faults constitute a portion of a fault complex which extends between faults 8 and 5, and three of them, 9, 10 and 12 continue into the Golconda quadrangle where they are numbers 45, 44 and 55. Faults 9 (G45) and 10 (G44) converge to the west and meet a little over a mile west of the Cave in Rock-Golconda boundary line, and with the Sheridan fault they form an elongate, triangular block whose western portion is Bethel sandstone. Fault No. 11 is a short cross fault separating a small rhomboidal block of Ste. Genevieve limestone at the east from the Bethel sandstone. Fault No. 12 has a more southwesterly direction than either 9 or 10, converging with the Sheridan fault which it joins about one-half mile west of the boundary line of the Golconda quadrangle. No. 12 and the Sheridan fault bound an elongate, triangular block of Pottsville sandstone. The triangular block between faults 10 and 12 is Ste. Genevieve limestone, the larger portion of the block being in the Golconda quadrangle.

Associated with this group of faults there is considerable mineralization. The John Belt mine on fault 9 (G45), and the Ben Belt mine on fault 10 (G44), besides a number of other prospects have been opened along these faults, and the Corn mine is situated near the junction of fault No. 9 with the Sheridan fault.

Fault No. 13 (Big Four Fault). The Big Four fault is subparallel with the Sheridan fault, and like that one it diverges from the Commodore fault to the southwest, its point of origin being about two miles southwest from that of the Sheridan fault. The distance between the Big Four and Sheridan faults varies from about three-fourths of a mile to less than one-third of a mile, they being most widely separated adjacent to the Commodore fault. The fault continues into the Golconda quadrangle where it is G56, and it has been traced southwestwardly to the southern boundary of that quadrangle. For the first two and one-half miles of its its course the downthrow is mostly on the southeastern side of the fault, but beyond the point of intersection of the Sandy Creek fault from the south, the throw is reversed in direction.

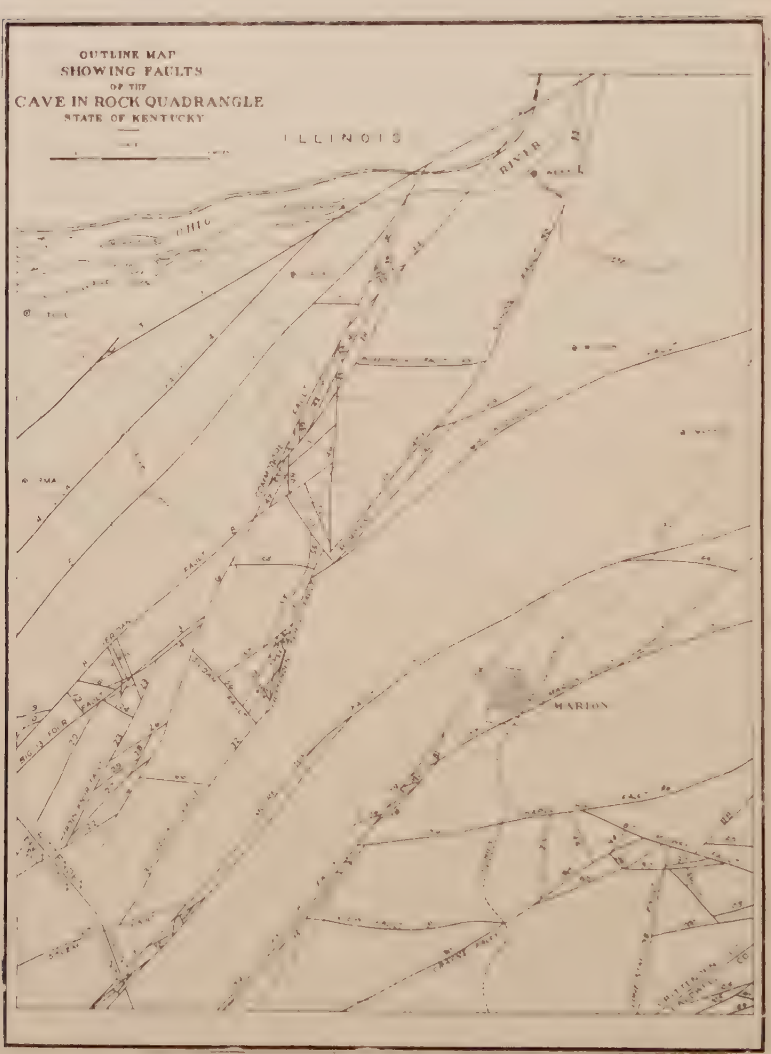
The Big Four fault is mineralized from the Big Four and Larue mines to the junction with the Commodore fault. The most important mining operations are at the Big Four mine, but many prospects have been opened, several of which have produced a considerable amount of fluorspar. The mining operations by the side of the Marion-Sheridan road, three-fourths of a mile out of Sheridan are situated along this fault near its junction with the Commodore fault.

Fault No. 14. Starting at about the Larue mine and continuing to the northeast to the Commodore fault, there is a narrow belt of quartzitic sandstone lying alongside and southeast of the Big Four fault. This belt is nowhere more than a few hundred feet in width and is separated from the sediments to the southeast by fault No. 14, This narrow and doubtless triangular mass of quartzite has been pinched between the two larger blocks on either side to such an extent that it is extensively fractured and recemented into quartzite, and it is not possible to determine with any certainty which one of the Chester sandstones it represents. Farther to the southwest the sandstone adjacent to the Big Four fault is the Hardinsburg sandstone, and this quartzite block may be from that formation, although there is a possibility of its being any one of the massive Chester sandstones from the Palestine down to the Bethel.

More recent field observations have shown that another fault, perhaps a continuation of No. 14 to the southwest, lies a short distance northwest of the Big Four fault. If it is a continuation of No. 14, this one and the Big Four fault must cross in an x-shape somewhere near the old LaRue mine. Crossing the narrow wedge between the Big Four fault and the one just mentioned there are at least three short cross faults.

Faults Nos. 15, 16, 17, 18 and 19. These five fractures constitute a group of cross faults between the Sheridan and Big Four Faults, although the first three must terminate against the southwestern extension of No. 14. They limit a series of fault blocks each one of which, proceeding from the northeast to the southwest, has slipped down relative to its neighbor to the northeast. The first large block between the Commodore fault and fault No. 15 is St. Louis limestone. The two blocks between 15 and 17 are of Ste. Genevieve limestone. The block between 17 and 18 is Renault limestone and Bethel sandstone. Between faults 18 and 19 a succession through the Golconda, Hardinsburg, Glen Dean and Tar Springs formations is present, and beyond fault No. 19 is the Kinkaid limestone overlain by the Pottsville.

It is altogether likely that there are other cross faults be-



**Fault Pattern Cave-in-Rock Quadrangle.
Geology by Stuart Weller**

tween the two master faults which have not been detected, especially in the large St. Louis limestone block, for towards the southwestern extremity of this block there are certain prospect diggings showing mineral, which may well be situated along minor fractures. Between faults 16 and 17 there is certainly another fault, probably essentially parallel with these two, situated only a few rods from No. 17, this being the fault upon which the Jones shaft of the Holly Mining Company is located. This fault is not great, both walls being Ste. Genevieve limestone, and unlike the other faults of the group the downthrown beds are on the northeast side.

Fault No. 15 of this group, upon which is located the Crystal Fluorspar mine, is unusual for the whole district in that it coincides with one of the peridotite dikes of the region. This coincidence of fault and dike is believed to be wholly accidental for there is no evidence that the fault continues throughout the entire length of the dike, although they do cross the Big Four fault together and continue to the Hardin Knob fault. The dike is known to extend nearly a mile beyond this last mentioned fault, but without any evidence of faulting. At the Crystal Mine the dike rock itself is much broken, with many of the fractures mineralized, showing that the movements have taken place after the intrusion of the dike.

The faults in this group which involve the St. Louis and Ste. Genevieve limestones at the surface have been richly mineralized, the Crystal Fluorspar mines and the several mines on the property of the Holly Mining Company being in the region between faults 15 and 17.

Fault No. 20 (Sandy Creek Fault). This fault diverges to the southwest from the Big Four fault at a point north of Hardin Knob. Its course is about north 30° east, and it continues across the southeastern corner of the Golconda quadrangle as G62. The wedge-shaped block bounded by the Sheridan and Sandy Creek faults consists of the Clore-Degonia-Kinkaid formations capped with Pottsville sandstone upon the higher hills.

Fault No. 21. This fault diverges to the south from the Sandy Creek fault at a point near the western boundary of the quadrangle. It continues into the Golconda quadrangle as G65 and after a course of a little more than two miles it joins the Salem fault.

Fault No. 22. This fault with a course about north 58° east, is nearly two and one-half miles in length, and joins fault No. 21 at the west and the Commodore fault at the east. The Sandy Creek, Big Four and Commodore faults, with fault No. 22, bound a large, much fractured, subrhomboidal block, in which the formations range in age from the Ste. Genevieve limestone to the Pottsville. The movement along the fault has dropped the beds down on the north side, the amount of dislocation varying from about 500 feet at the southwestern extremity to probably less than 100 feet at the point of junction with the Commodore fault. On the southeast side of the fracture the Ste. Genevieve limestone is present throughout nearly the entire distance. There is known to be some mineralization along this fracture, although none of the mines have been in operation during the progress of the present survey.

Fault No. 23 (Hardin Knob Fault). This fault is subparallel with the Commodore fault to the east and the Sandy Creek fault to the west, and lies about half way between them. It is about four miles in length, terminating at fault No. 14 at the north, and at fault No. 22 at the south, and bisects the rhomboidal block mentioned in the last paragraph, into two nearly equal parts. The downthrow is on the west side of the fault through its entire extent.

Fault No. 24. This is a cross fault cutting off the north end of the parallel sided block between the Hardin Knob and Sandy Creek faults. The downthrow is perhaps 60 feet on the south side. North of the fault the Menard limestone, the base of the Palestine sandstone the Tar Springs sandstone and the Vienna limestone are in contact with it, and on the south the Palestine sandstone is present, passing up into the Clore-Degonia-Kinkaid formations, with the Pottsville capping Hardin Knob.

Field observations which have been made since the original survey of this quadrangle, have shown that the triangular block bounded by the Big Four fault, the Hardin Knob fault, and fault No. 24, is most complexly fractured. During 1925 and

1926, Mr. A H. Reed carried on much prospecting within this block, and the many pits which have been dug have permitted the observation and identification of many rock exposures which were completely hidden before this work was undertaken. No less than five distinct faults cut this block, bringing to the surface at various places all of the Chester formations from the Hardinsburg sandstone to the Palestine sandstone, inclusive. The positions of these faults are shown upon the geological map.

Fault No. 25. This is another cross fault in the same block as the last, cutting its southern end. The downthrow is on the northeast side and may be as much as 100 feet. On the northeast side of the fault is the Menard limestone and Palestine sandstone which dip beneath the higher beds in Hardin Knob to the north. Southwest of the fault is the Tar Springs sandstone.

Faults Nos. 26, 27, 28, and 29. These four faults cross the eastern half of the large subrhomboidal block surrounded by the Sandy Creek, Big Four, Commodore, and fault No. 22. Fault No. 26 is situated at about the mid length of the block and is subparallel with the Big Four fault and fault No. 22. No. 28 is subparallel with the Commodore and Hardin Knob faults and cuts off about the eastern third of the rhomboidal block lying between Nos. 26 and 22. Faults No. 29 and No. 27 are subparallel with fault 26, terminating at No. 28 on the east and the Hardin Knob fault on the west, they divide the larger western portion of the whole block between No. 26 and No. 22 into three nearly equal parts, the southern one of which is again divided by a short cross fault, subparallel with the Hardin Knob fault, into two somewhat unequal portions. The narrow block between the Commodore fault and No. 28 is also divided by a short cross fault subparallel with No. 26, into two blocks, the more northern of which is the smaller.

The delineation of faults 27 and 28 is somewhat different in the geological map than in the previously published fault pattern map of the quadrangle, but the changes shown are warranted by more recent field studies. Likewise the two shorter cross faults mentioned above were not shown in the earlier map.

In this fault complex, two of the blocks, the one lying between No. 26 and No. 29, and the more southern one between the Commodore fault and No. 28, contain only sandstone outcrops so far as it has been possible to discover, and without some associated limestone formation the determination of the age of the sandstone is rendered somewhat uncertain. However, the lithologic character of the sandstone in the first of the blocks mentioned suggests Palestine, and it is so mapped, and that of the second one seems to be Cypress. The large northern block between the Commodore and Hardin Knob faults, north of No. 26, the northern block between the Commodore fault and No. 28, and the block bounded on the north and south by faults No. 29 and No. 27, are all occupied in large part by the Tar Springs sandstone, in each case with outcrops of Glen Dean limestone showing beneath it. The two smaller blocks between Fault No. 27 and No. 22 are occupied by formations ranging in age from Ste. Genevieve up to Cypress sandstone.

Fault No. 30 (Heath School Fault). This is one of the long faults of the quadrangle. Its point of origin is in the fault complex north of Crittenden Springs, and it continues in a somewhat arcuate course with an average direction of north 30° east, for about ten and one-half miles, where it terminates at fault No. 2. It passes about one-fourth mile east of Heath School, two and one-fourth miles southwest of Weston, and forms the northern portion of the eastern boundary of the Glendale faulted belt. The maximum dislocation along the fracture is probably somewhat more than 100 feet. in its southern portion the downthrow is on the west, but north of the intersecting fault No. 69 the downthrow is on the east.

Fault No. 31 (Crittenden Spring Fault). This fault forms the eastern boundary of the Glendale faulted belt in its central portion. It originates in the complexly faulted area north of Crittenden Spring, near the southern extremity of the Heath School fault, but the two faults apparently are not in actual contact. The extent of the fault is a little over three miles and the downthrow is on the west side throughout its entire length, its average direction being about north 20° east. This fault is mineralized more or less throughout its entire length, and has been extensively prospected. The mining operations which have been conducted at Crittenden Spring are along this fault, and the Franklin mine is situated upon it near its southern extremity. The Mary Belle and the Old Columbia mines are situated near this structure, but they are not upon the main fault, but rather upon some shorter connection faults.

Fault No. 32 (Levias Fault). This is a connecting fault, continuing to the southwest the Crittenden Spring fault structure. The junction of the two is just south of the Franklin mine, and the total length of the Levias fault is about five miles to the point where it joins the Salem fault. It forms the southern portion of the eastern boundary of the Glendale faulted belt. Throughout its extent the downthrow is on the west, and its direction is about north 35° east. This fault is mineralized in places, the Ada Florence and Keystone mines being situated upon it, and prospecting has been conducted along it in a number of localities.

The three faults, Heath School, Crittenden Spring and Levias, together were interpreted by Ulrich as a single fault which he called the Columbia fault and drew in a straight line from end to end, extending it southwestward to the Cumberland River. Ulrich's name was taken from the Old Columbia mine which really is not on the main fault at all, and if the name Columbia were given to any fault it should be applied to a short one which is included in the fault complex lying west of the Crittenden Spring fault.

Fault No. 33. This fault lies in a nearly north-south direction east of Weston, joining fault No. 2 at the north and No. 30 at the south. Its length is nearly one and three-fourths miles. These three faults together outline a narrow elongate, wedge shaped fault block, pointed to the south, which is downdropped relative to the block lying to the east, towards its southern extremity, but is upthrown at the north, and against which the block lying to the west is still farther downdropped. The surface formation in nearly the whole of the triangle is Menard limestone, but with the hills near the north extremity capped with Palestine sandstone.

Fault No. 34. This fault, having a direction of about north 40° east, with a length of about five miles, presumably joins fault No. 2 about north of Weston. Its southern termination is at its junction with the Commodore fault about one-half mile south of Dunn Spring Church. The triangular block of which this fault forms the southeastern side, must reach across the Ohio River into the bottom lands of Hardin County, Illinois, but the only rock exposures are south of the Ohio River. The village of Fords Ferry lies within this block about midway between the two sides where they intersect the river bank. The sandstone at Fords Ferry is Cypress, but one and one-half miles southeast of that place the Renault limestone is well exposed in the southwardly facing hillslope, overlain by the Bethel sandstone. The Paint Creek division between the Bethel and Cypress sandstones has not been seen at any point in the Fords Ferry hill, although it undoubtedly is present.

Faults Nos. 35, 36, and 37. The southwestern wedge-shaped termination of the fault block described in the last paragraph is broken by three short cross faults. The tip of the larger triangle, for a distance of more than a mile along its southeastern side, and a shorter distance on the opposite side, consists of a triangle of Ste. Genevieve limestone cut off by fault No. 35, which has not dropped as deeply as the main portion of the larger block. North of fault No. 35 the two cross faults 36 and 37 traverse the wedge-shaped point between faults 35 and the Commodore fault, cutting off a small triangular block of sandstone, probably Bethel, and next to this a trapezoidal block of Fredonia limestone with a hill at the north capped by Rosiclare sandstone.

It is apparently the areas of oolitic Ste. Genevieve limestone in this locality, that were mistaken by Ulrich to be Spergen limestone, and so indicated in his geological map of the fluorspar district of western Kentucky.

Fault No. 38. This is another fairly long fault, forming one side of an elongate triangular block which is much broken up by subordinate faults. The northern terminas of the fault is at a junction with fault No. 34 nearly one and one-half miles from the southern end. With a length of about four and one-half miles the fault terminates at the Commodore fault a little over a mile north of the termination of the Sheridan fault, but on the opposite side. The bounding faults of the block are the Commodore fault and Nos. 34 and 38.

Faults Nos. 39 and 40. As so commonly occurs throughout this entire faulted district, the wedge-shaped termination of the larger fault block last mentioned, is traversed by cross faults. In this block there are two such faults, No. 39 nearly north and south in direction, and No. 40 nearer the tip of the wedge with a course somewhat northeasterly. The narrow triangular block at the tip of the wedge is sandstone, probably Bethel or Cypress. The trapezoidal block lying next to it in a northwest direction is Fredonia limestone.

Faults Nos. 41, 42, 43, and 44. The main portion of the larger triangular block, lying northeast of fault No. 39, is split longitudinally by two faults which are subparallel with the Commodore fault, these being Nos. 41 and 42. Between fault No. 41 and the Commodore fault there is a narrow sandstone ridge, doubtless of the Cypress sandstone. The narrow block between faults 42 and 43 is Fredonia limestone in its southern part with a capping of Rosiclare sandstone. North of where a tributary of Hurricane Creek crosses the block the high hill is capped with Bethel sandstone, with exposures of Renault limestone both on the south and north slopes. The northern portion, a mile and one-half in length is separated from the southern part by a cross fault, No. 44, to the north of which the Cypress sandstone is exposed, with the Paint Creek shale and Bethel sandstone farther north.

The last of the narrow, subordinate blocks in the group under discussion, lying between faults 41 and 38, is also divided by an oblique cross fault, No. 43, into two parts, the part south of the fault being Fredonia limestone and that north being Cypress sandstone.

The complexly faulted portion of the wedge between the Commodore fault and fault No. 38, at the southern extremity of the larger triangular block, is richly mineralized, the several openings known as the Beard mines being situated upon these fractures.

Fault No. 45 (Pickering Hill Fault). This fault is directed nearly east and west, joining fault No. 38 on the west and the

Heath School fault on the east. It crosses the Fords Ferry road near the top of Pickering Hill. The dislocation is only about 60 feet with the downthrow on the south side, and because of the thickness of the formations there is little change in crossing the fault. In that whole portion of the Glendale faulted belt from fault No. 46 to Weston on the Ohio River, the hills are capped with Hardinsburg sandstone, beneath which there is a more or less abrupt slope underlain by the Golconda formation, the lower ground being Cypress sandstone with some Paint Creek and Bethel in the ravine-like valley of Crooked Creek. In the block south of the Pickering Hill fault, because of its downthrow, the Paint Creek and Bethel have not been recognized.

Fault No. 46. This fault is nearly north-south in direction, with a length of about three miles. Its north end is in junction with fault No. 38 a little over one-half mile southwest of the western termination of the Pickering Hill fault. The southern extremity is situated in the complexly faulted area north of Crittenden Spring, near the southern extremity of Heath School fault and the northern end of Crittenden Spring fault.

The block lying east of fault No. 46 is rather large, bounded also by the Heath School and Pickering Hill faults, it is in general triangular in outline, but with the western tip of the triangle truncated by fault No. 38. The formations exposed in this block are Cypress sandstone in the valley floors, Golconda limestone and shale upon the hill slopes, and Hardinsburg sandstone capping the hills.

West of fault No. 46 there is much complex faulting, and no less than four distinct fault blocks come in contact with it. Along three of these fault blocks the dislocation is downward on the west side, but on the fourth the downthrow is on the east.

Fault No. 47. This fault has a direction of about north 55° east, and is about one and three-fourths miles in length, reaching from fault No. 46 on the east to the Commodore fault on the west. In combination with these two faults and with the southern portion of fault No. 38, a trapezoidal block is outlined in which there are a number of subordinate faults. The point of junction of fault 47 with the Commodore fault nearly coincides with that of the Sheridan fault on the opposite side, and it is possible that this is nothing more than a projection of the Sheridan fault beyond the Commodore fault to No. 46. The downthrow is upon the north side through the entire length of the fault.

Faults Nos. 48, 49, 50, and 51. The trapezoidal block mentioned in the last paragraph is traversed by four distinct faults which subdivide it into five subordinate blocks. Fault No. 48, with a direction a little west of north, divides the larger block into an eastern and western portion. The western portion is again divided by faults 49 and 50 into three smaller blocks. The smallest of these, triangular in outline, at the northwest, consists of Ste. Genevieve limestone. The second one, between faults 49 and 50 is much tilted Palestine sandstone, and the third, a triangular block at the southeast, is Menard limestone in the creek bottom and Palestine sandstone higher up.

The eastern and larger portion of the trapezoidal block is divided by fault No. 51, whose direction is subparallel with fault No. 47, into a northern and a southern block. In the northern block there is a stratigraphic succession from the Hardinsburg sandstone, through the Glen Dean limestone, into the Tar Springs sandstone. The southern block is made up entirely of Tar Springs sandstone.

Faults Nos. 52 and 53. These two faults have a north-west direction and are about one and one-fourth and one and one-half miles in length. Both of them join fault No. 47 at their northwestern extremities. No. 53 forms, with Nos. 46 and 47, a triangular block which is divided into two parts by fault No. 52. Towards its southeastern extremity fault No. 53 connects with the southern extremity of No. 46 and the northern extremity of the Crittenden Spring fault, and continues to fault No. 68, the Klondike fault, where it is terminated. The triangular block lying between faults 52, 46, and 47, is entirely of sandstone, apparently the Cypress, and the block between 52 and 53 is Glen Dean limestone.

Fault No. 54. This east-west fault passes just north of Glendale School, and joins the Commodore fault on the west and the Crittenden Spring fault on the east. It is the south boundary of a five-sided block whose other sides are the Commodore and Crittenden Spring faults, and Nos. 47 and 53.

Fault No. 55. The five-sided block last mentioned is traversed near its eastern side by fault No. 55. The small block east of this fault is Golconda limestone and shale. The much larger portion lying between fault No. 55 and the Commodore fault, exhibits an excellent section from the Vienna limestone through the Waltersburg sandstone, the Menard limestone, the Palestine sandstone, the Clore-Degonia-Kinkaid formations, into the Pottsville sandstone. A most excellent exhibition of the Vienna, Waltersburg, Menard and Palestine may be seen in the bluffs rising from Hurricane Creek, the higher formations being well shown in the next escarpment to the southwest.

Fault No. 56 (Siloam Fault). This fault has a direction of north 40° west, and connects the Levias fault on the southeast with the Commodore fault on the northwest. Its southeastern termination is between the Ada Florence and the Keystone mines. It passes along the valley opposite Tanyard Spring and a little west of Siloam School, its length being about one and three-quarters miles. With the Commodore and Crittenden Spring faults, and fault No. 54, it surrounds a large sub-trapezoidal block whose eastern border is an especially complexly faulted belt.

Faults Nos. 57 and 58. These two faults, both with a northeasterly direction, separate the fault complex of the eastern border of the block lying between fault 54 and the Siloam fault, from the larger western unfaulted portion. Fault 57 has a more easterly component in its direction and No. 58 terminates against No. 57. The large block west of these two faults, extending to the Commodore fault, consists of the Kinkaid limestone and shales in the eastern and southern slopes of the large hill occupying it, the capping of the hill being massive Pottsville sandstone.

The elongate fault block along the valley of Hurricane Creek, between fault 58 and the Crittenden Spring fault seems to be for the most part Menard limestone, although only two good exposures of the formation have been observed, with the Palestine sandstone overlying it.

Fault No. 59. This fault terminates at fault 57 at the north, and against the Siloam fault at the south, and between it and the Crittenden Spring fault lies the complexly faulted area extending from the Franklin to the Columbia mine. West of the fault, between it and fault No. 57, there is a triangular block in which there is a stratigraphic succession from the Tar Springs sandstone at the Tanyard Spring through the Vienna and Waltersburg formations which are mostly hidden, the Menard limestone and into the Palestine sandstone.

Faults Nos. 60, 61, 62, 63, 64 and 65. These are the principal faults in the fault complex extending from the Ada Florence and Franklin mines on the south to the Columbia mine on the north. It is not unlikely that other lesser faults may be present which can not be determined under the surficial covering of the district. Fault No. 60 passes diagonally from about the junction of faults 59 and 57, to a point near the Franklin mine. Fault 61 is subparallel with 57 and only about one-eighth mile distant from it in a southeast direction, it apparently continues across No. 60 and connects the Crittenden Spring fault with No. 59, with a total length not exceeding one-half mile. It is upon this short cross fault that the old Columbia mine is located. The small triangular block west of No. 60 and northwest of 61 is Vienna limestone and Waltersburg sandstone, and the larger rhomboidal block east of No. 60 seems to be Golconda limestone and shale.

Fault No. 62 passes from the Crittenden Spring fault on the east, in a southwesterly direction converging with No. 59, and joins the Siloam fault about one-eighth of a mile from the junction of No. 59 with the same fault. The block west of fault No. 60 and between 61 and 62, is for the most part a prominent hill which is capped with Tar Springs sandstone, but on the slopes of the hill at the north, east and south, the Glen Dean limestone is exposed. East of fault 60, between 61 and 62, there is a subrhomboidal block whose eastern boundary is the Crittenden Spring fault, and in which are two subordinate faults. Fault 63 joins 61 and the Crittenden Spring fault, and with these two surrounds a small triangular block of Ste. Genevieve limestone lying west of the Crittenden Spring fault. Fault No. 64 is essentially parallel with the Crittenden Spring fault and only a few rods west of it, it is only about three-eighths of a mile in length, and forms the west boundary of a narrow sandstone block which is probably Bethel or Cypress. The Mary

Belle mine is situated upon this short fault and not upon the main Crittenden Spring fault. Between faults 64 and 60 is a small, irregularly four-sided block just west of the Mary Belle mine, which is Bethel sandstone on the hill top with Renault limestone upon the eastern slope.

Between faults 62 and the Crittenden Spring fault, there are three subordinate fault blocks. The most northeasterly one is a narrow, elongate triangle, formed by the continuation of fault 60 in a southerly direction beyond No. 62. This block is entirely of sandstone, probably Cypress. Fault No. 65, extending northwest from a point at or near the junction between No. 60 and the Crittenden Spring fault, in a direction subparallel with the Siloam fault, forms the southwestern side of a small triangle which is Tar Springs sandstone above with Glen Dean limestone upon the hill slope to the north. The block between No. 65 and the Siloam fault is somewhat larger, with Golconda limestone and shale well exposed along the main road near the Franklin mine, and with Hardinsburg sandstone on the hill above.

Fault No. 66. This is an east-west fault between the Levias and Commodore faults, originating near the mouth of the hollow just west of Levias and continuing for one and one-fourth miles to the Commodore fault. The downthrow is on the north side, bringing Golconda limestone and shale into fault contact with the Cypress sandstone south of the fault.

Fault No. 67. (Salem Fault). The direction of the Salem fault is nearly north 70° east. It originates at the Moore's Hill fault at or near the Eagle fluorspar mine, three miles northeast of Salem, and extends in a southwesterly direction through the southern edge of Salem, continuing into the Golconda quadrangle as G64. A little over one and one-fourth miles from its point of origin on the Moore's Hill fault is a junction of the Levias fault with the Salem fault, which is the southern terminus of the former.

Fault No. 68 (Klondike Fault). This fault is named from the Klondike mine which is one of the Memphis group of mines about three and one-half miles northwest of Marion. The fault originates in the complexly faulted region north of Crittenden

Spring, and diverges from the Crittenden Spring fault to the east, with an initial direction of about north 60° east. It has been traced for more than nine miles to the point where it crosses the eastern boundary of the Cave in Rock quadrangle. Its course is somewhat arcuate and its direction on leaving the quadrangle is about north 75° east. Throughout its entire extent in the quadrangle the dislocation is about 40 feet with the downthrow on the north side. Towards its southwestern extremity the fault is mineralized and has been prospected at various places.

Fault No. 69. This is a short fault a little over two miles in length which is subparallel with the Klondike fault, and lies from one-half to three-fourths of a mile north of it, and diverges to the east from the Heath School fault about three miles from its southern terminus. The wedge-shaped area between this and the Heath School fault is downdropped 60 or more feet at the tip, but near Crooked Creek the fault terminates and beyond this no dislocation can be detected between the Klondike and the Heath School faults.

Fault No. 70 (Memphis Fault). This fault is essentially parallel with the Heath School fault and lies about one-fourth mile southeast from it. It terminates in a junction with the Klondike fault at the south, and joins fault No. 69 at the north. The amount of dislocation is small, being less than 40 feet with the downthrow upon the northwest side. The fault is mineralized and has been prospected at various places, and the Memphis mine is situated upon it.

Fault No. 71 (Moore's Hill Fault). This is one of the longest faults in the Cave in Rock quadrangle, its extent being more than fifteen miles, in addition to continuing eastward into the Providence and southwestward into the Eddyville quadrangles. Throughout its entire length the downthrow is upon the southeast side, the greatest dislocation being northwest of Marion where it must be between 300 and 400 feet. The fault follows an arcuate course, its direction becoming more easterly in a northeast direction. Where it enters the quadrangle from the southwest its direction is approximately north 45° east, and where it leaves the quadrangle at its eastern boundary the direction is about north 75° east. The Moore's Hill fault forms the northwestern boundary of the downdropped Marion belt which has been mentioned in an earlier portion of this report.

Fault No. 72. For nearly one-half of its length from the point where it enters the Cave in Rock quadrangle from the southwest, the Moore's Hill fault has a companion fault which is nearly parallel with it, and situated less than one-fourth mile to the southeast. At a point about west of Marion the two faults seem to be joined. This fault is No. 72. From the junction of the faults a narrow belt of much crushed and deformed quartzite may be traced southwestwardly to the south boundary of the quadrangle, this quartzite belt being limited by the two faults. An excellent exhibition of this crushed quartzite zone may be seen in the public road at Moore's Hill on the Marion-Salem road, the Moore's Hill fault being situated at the foot of the hill and fault No. 72 at the top. The sandstone which has become quartzitic probably varies from place to place, being the formation which lies next to it in the main fault block to the southeast. At Moore's Hill it is doubtless the Tar Springs sandstone, where the New Salem-View road crosses the belt it is quite certainly the Hardinsburg sandstone, and farther south at the Crittenden-Livingston County line the Cypress.

This crushed, quartzitic zone is highly mineralized in places, especially south from a point east of New Salem, the mineralization being richest, apparently, along the Moore's Hill fault side of the belt. The Eagle Fluorspar mine northeast of New Salem, and the Cullen mine southeast of Salem, are so situated. The Watson mine, just southeast of the Eagle Fluorspar mine is within the crushed zone between the two faults.

In the southern portion of the quartzitic belt limited by the Moore Hill fault and No. 72, from the southern boundary of the quadrangle to a point a little north of the New Salem-View road, a number of diagonal cross faults within the belt have been detected, which were not shown upon the earlier fault pattern map. No less than eleven such faults are now recognized upon the geological map, and with sufficient knowledge the presence of others could undoubtedly be established. It is not unlikely that similar cross faults exist throughout the entire linear extent of this narrow belt, but in its more northern portion no sufficient evidence for the proper location of such faults has been secured. So far as has been determined in this faulted portion of the belt, the Ste. Genevieve, Renault, Bethel, Cypress, Golconda, and Hardinsburg formations have been identified, the formations in general becoming higher in the column in passing to the northeast.

Fault No. 74 (Clay Lick Fault). The Clay Lick fault is essentially parallel with fault No. 72 and with the southwestern portion of the Moore's Hill fault, and is located about one and one-half miles southeast of No. 72. It crosses the southern boundary of the quadrangle just west of Clay Lick Creek and it parallels the valley of that creek for nearly four miles. The fault is nearly straight and continues in the Cave in Rock quadrangle for nearly ten miles to the point where it joins the Moore's Hill fault north of Marion, because of the change in direction of that fault towards the east. Except for a short distance near the junction of the Marion fault with the Clay Lick fault, the downthrow along this fracture is on the northwest side, the greatest amount of dislocation, about 300 feet, being near the mouth of Preacher Creek. This fault, with the Marion fault, forms the southeastern border of the Marion downdropped belt.

In the southwestern-most three miles or so of the Clay Lick fault in the Cave in Rock quadrangle, it is more or less mineralized, and a number of mines and prospects have been opened along it or in the quartzite belt lying between it and fault No. 75. Along this portion of the fault are the White, the Susie Beeler, and the Ebbie Hodge mines, besides numerous prospects.

Fault No. 75. This fault parallels the Clay Lick fault in about the same manner that No. 72 parallels the Moore's Hill fault. The two are not more than one-eighth of a mile apart and they form the two sides of a much fractured and crushed quartzite belt. Its length within the quadrangle is four miles to where it terminates against the Chapel Hill fault.

The belt between the Clay Lick fault on one side and fault No. 72 and the Moore's Hill fault on the other, is the southwestern portion of the downdropped Marion belt, and in it there is a regular succession of formations from the southwest to the northeast. The Renault escarpment, capped by Bethel sandstone is situated just south of the boundary line of the quadrangle. The Paint Creek shale bed has not been seen and the position of this formation between the Bethel and the Cypress sandstones is not marked by any escarpment. The Golconda escarpment is well exhibited just south of Fairview School and to the north is the long cuesta slope of Hardinsburg sandstone. The Glen Dean escarpment extends east and west from Cisco School, and to the northeast the wedge-shaped portion of the block is occupied by the Tar Springs sandstone, except where the top of the Glen Dean is exposed by erosion at two places, and where one hillslope is covered by the Vienna limestone.

At one point in the quartzitic belt between the Clay Lick fault and No. 75, just below the mouth of Preacher Creek, there is a considerable outcrop of limestone which seems to be the Glen Dean. This outcrop must be bounded by short cross faults on both sides, which doubtless are approximately as shown in the geological map, although their exact direction can not be certainly established. It is not unlikely that this belt further south is also cut up by similar diagonal cross faults, as is the Moore Hill belt, but the positions of such faults have not been determined. The whole of this belt southwest from the Glen Dean limestone outcrop has been colored as Cypress sandstone on the geological map without sufficient evidence, and it must be understood that some other sandstone formation, most likely Hardinsburg, may constitute a portion of it.

Fault No. 76. This is a short, divergent fracture from the Clay Lick fault to the west, a little north of east from Cisco School. Probably it is not more than one-half mile in length, with the downthrow on the north side.

Fault No. 77 (Marion Fault). The Marion fault diverges to the east from the Clay Lick fault, at a point about two miles southwest of Marion. Its course is slightly arcuate, and its direction is essentially parallel with the more eastern portion of the Moore's Hill fault. It crosses the southeastern corner of the corporation of Marion, and may be seen crossing the Tribune road about one and one-half miles east of the public square in Marion. It leaves the Cave in Rock quadrangle at the eastern boundary a little more than one-half mile north of the Tribune road.

Towards its eastern extremity the block between the Marion and Moore's Hill fault is traversed by two diagonal cross faults, but to the west of these faults a geological succession is well exposed from the Hardinsburg sandstone at the junction of Clay Lick and Moore's Hill faults, in a southeasterly direction, through the Glen Dean limestone along Rush Creek, the Tar Springs sandstone from Rush Creek to a line southeast of the Illinois Central Railway track, then through the Vienna, Waltersburg and Menard in the hillslope southeast of the railroad, into the Palestine sandstone capping the hill.

The Marion fault has been found to be richly mineralized at the Lucile Mine in Marion, but prospecting along it elsewhere has not been profitable as yet.

Faults Nos. 78, 79, and 80. In the vicinity of the junction of the Marion fault with the Clay Lick fault, there has been considerable fracturing on both sides of the Marion fault. One fault, No. 78, crosses the obtuse angle to the southeast, between these two faults. This fault is a little less than two miles in length, and with the other two faults it surrounds a narrow and elongate triangular block which itself is crossed by two subordinate faults Nos. 79 and 80, cutting the larger block into three smaller ones, all of which are downdropped to different degrees, successively from the south to the north. The southernmost of the three blocks is a long, narrow area of Glen Dean limestone with overlying Tar Springs sandstone, the one next north, between faults 78 and 79 is Tar Springs sandstone, and the most northerly one is mostly Waltersburg sandstone with one small patch of Vienna limestone which has been exposed by erosion. All of these blocks lie adjacent to Cypress sandstone on the east.

Fault No. 81. The true position of this fault is not certain, but the outcrops are such as to show that the point of the thin wedge between the Marion and Clay Lick faults has been broken off and downdropped, but since a considerable area in that vicinity is wholly without outcrops of any sort, the exact position of the fracture can not be seen. The triangular block thus formed is occupied by Vienna limestone and Waltersburg sandstone, both of which formations are well exposed.

Fault No. 82. This is a diagonal fault between the Marion and the Moore's Hill faults, although its eastern termination and junction with the Moore's Hill fault is beyond the boundary of the Cave in Rock quadrangle. The wedge-shaped block between fault No. 82 and the Marion fault has dropped downward relative to the strata on both sides, and brings the Kinkaid limestone down to the level of the Palestine sandstone on the north, and to the level of the Menard limestone on the south. In the mapping, the sandstone towards the western extremity of this wedge has been indicated as Palestine, but it is possibly a Degonia equivalent.

Fault No. 83. In the extreme tip of the wedge between No. 82 and the Marion fault, a short cross fault has been developed which has permitted a small, triangular block of Kinkaid limestone to drop downward more deeply than the broader portion of the segment farther east.

Fault No. 84. This fault has a diagonal direction, starting from the Moore's Hill fault nearly opposite the point of origin of fault No. 82. It passes in a nearly easterly direction for a distance of two miles, where it joins No. 82. Like the wedge-shaped block opposite it, the wedge between No. 84 and the Moore's Hill fault is Kinkaid limestone, which has been downdropped relative to the strata on the two sides. It is possible that further field work in the quadrangle lying east of Cave in Rock will show that this fault, instead of No. 82, is the one which continues eastward into that quadrangle, in which case the linear extent of No. 82 will be curtailed, and No. 84 will be extended.

Fault No. 85. As in the case of the wedge opposite it, the tip of the wedge between No. 84 and the Moore's Hill fault is fractured by a short cross fault, No. 85, but unlike the tip of the other wedge this one has not slipped downward so far as the main portion of the segment farther east. In the small triangle west of fault 84 the Vienna limestone and Waltersburg sandstone are exposed at the surface.

Fault No. 86 (Chapel Hill Fault). The Chapel Hill fault originates at the Clay Lick fault about one and one-half miles southwest of the point of origin of the Marion fault. From this point its general direction is about north 80° east. It continues for a distance of about seven and one-half miles in the Cave in Rock quadrangle and crosses into the Providence quadrangle a little south of Piney Creek. Throughout the greater portion of its length the downthrow is on the south side, although at its point of origin the dislocation is in the other direction. The greatest amount of dislocation is towards the east where it must be about 350 or 400 feet, with the Pottsville sandstone brought into contact with the Hardinsburg.

The block lying between the Chapel Hill and Marion faults is one of the larger fault blocks of the district, and in it there is a complete sequence of Chester formations from the Cypress sandstone at the west to the Palestine sandstone at the east border of the quadrangle.

The Chapel Hill fault is well shown at the foot of Cochran hill on the Princeton road a little over two miles south of Marion. Again the fault scarp is quite evident along the road from Marion to Piney Fork at the road corner a little more than four miles out of Marion. There is also a good exhibition of the fault in Black's Branch of Piney Creek and across the hill to the east.

Fault No. 87 (Midway Fault). The Midway fault diverges from the Chapel Hill fault to the southeast, three and one-quarter miles from the east boundary of the quadrangle, and passes just north of the Midway School, its direction being about north 72° west. It continues eastward into the Providence quadrangle. The wedge-shaped block between the Chapel Hill and Midway faults is downdropped relative to the areas on either side, and is traversed by other faults to the southeast of Butler Creek. An excellent exhibition of this fault may be seen in the south bank of Butler Creek a short distance north of the Piney Fork road.

Faults Nos. 88 and 89. These two faults lie between the Chapel Hill and Midway faults in the area southeast of Butler Creek. No. 88 diverges from the Midway fault a little over one mile from the eastern boundary of the quadrangle, its direction being north 45° east, and it continues eastward into the Providence quadrangle. The block between the Chapel Hill, Midway and No. 88 faults, exhibits the upper surface of the Menard limestone along the bed of Butler Creek, with Palestine sandstone in the lower portion of the bluffs on either side. Above this comes the Clore-Degonia-Kinkaid formation around the lower slopes of Pilot Knob and in the flat country to the west, with Pottsville sandstone forming the Knob itself and capping the ridge to the west as far as the Marion-Piney Fork road.

Fault No. 89 extends eastward from No. 88, with a nearly east-west direction, and continues into the Providence quadrangle. The block lying to the north, between faults 88 and 89, has slipped downward less than those on either side and is occupied by the Menard limestone capped by Palestine sandstone. The block to the south, between fault No. 89 and the Midway fault, shows good exposures of Kinkaid limestone and shale in the hillslope south of Piney Fork Church, with a capping of Pottsville sandstone.

Fault No. 90 (Crayne Fault). The Crayne fault has a direction of about north 60° east, passing through the northern edge of Crayne. To the northeast it joins the Midway fault one and one-fourth miles from its junction with the Chapel Hill fault. To the southwest it crosses the southern boundary of the Cave in Rock quadrangle about one-half mile east of Reiter Corner. The amount of dislocation is nowhere large, and the direction of downthrow varies from place to place by reason of the several fault blocks which adjoin the fracture. The fault is not known to be distinctly mineralized within the limits of the quadrangle, but mining operations have been conducted along its extension to the southwest in the Eddyville quadrangle.

Fault No. 91 (View Fault). The View fault has a general east-west direction, being parallel with the Chapel Hill fault, and connects fault No. 75 with the Crayne fault. The junction with fault 75 is not far from the Susie Beeler mine, near the road from View to Salem, the junction with the Crayne fault being right at Crayne. The location of the fault is about one-half mile north of View. The dislocation increases from west to east with the downthrow on the north, being 50 feet or less at the junction with fault No. 75 and over 200 feet at Crayne.

Faults Nos. 92, 93 and 94. These three faults cross the block limited by the Chapel Hill-Midway faults on the north, and the View-Crayne faults on the south, towards the eastern end, each block from west to east being dropped successively deeper, although the dislocations are all moderate in amount, perhaps in no case exceeding 100 feet. Along fault 92 the Menard limestone on the east side is in fault contact with the Tar Springs sandstone on the west. In the eastern portion of the block between faults 92 and 93 the Palestine sandstone overlies the Menard limestone. The entire block between faults 93 and 94 is Palestine sandstone which has dropped down to be in fault contact with the Menard limestone at the junction of fault 93 with the Crayne fault. The triangular block east of fault 94 is entirely of Kinkaid limestone which has dropped down in fault contact with the Palestine sandstone to the west.

Fault No. 95. This fault diverges from the south side of the Crayne fault about one-half mile northeast of Crayne, and joins the Midway fault at its northeastern terminus, it is about two and one-half miles long and for much of its extent it is subparallel with the Crayne fault and less than one-half mile distant from it.

Fault No. 96. This is a short cross fault between the Crayne fault and fault No. 95. The block to the west of it is the larger and is dropped relative to the one to the east, and is also downthrown relative to the areas to the north and south, it is composed wholly of Palestine sandstone except for a small area of Menard limestone at its northeastern corner. The block to the east of the fault is also of Menard limestone and Palestine sandstone, but the contact between the two formations is at a higher level than in the eastern block.

Fault No. 97. This fault is less than two miles in length with a general east-west direction, joining fault 95 on the west, with the Midway fault on the east. It apparently crosses the Lone Star fault without offset. Throughout its entire length the downthrow is upon the north side. In the fault block north of No. 97 and west of the Lone Star fault, the Menard limestone and Palestine sandstone are exposed, but the contact between the two formations is somewhat higher than in the adjacent block north of fault No. 95.

Fault No. 98 (Lone Star Fault). This fault, with a direction of about north 10° east, connects fault No. 104 on the south, a little beyond the south border of the quadrangle, and the Midway fault on the north. It apparently crosses fault No. 97 without offset near its northern extremity. Its position is about one-fourth mile east of the Lone Star School. In the southern part of its course the downthrow is on the east, the amount of displacement being 150 feet or more. For a mile south of fault 97 the downthrow is on the west side, the amount of dislocation varying from 50 feet to perhaps 150 feet. North of fault 97 the downthrow is again on the east side.

Fault No. 99. This is a short fault sub-parallel with No. 97. It splits the triangular block lying north of 96 and east of the Lone Star fault in an east-west direction. The narrow block between 99 and 97 is Kinkaid limestone, and the triangular block north of 99 is Palestine sandstone.

Fault No. 100. This fault, with a direction of about north 80° east, extends eastwardly from the Lone Star fault which it joins about one and one-half miles from the southern boundary of the quadrangle. It continues in an eastwardly direction into the Providence quadrangle. For a little more than one-half of its extent within the quadrangle, towards the west, the dislocation is not far from 100 feet, with the downthrow on the south, bringing the Tar Springs sandstone in contact with the Hardinsburg. Farther east the downthrow is on the north, bringing the Palestine sandstone against the Tar Springs.

Fault No. 101. This fault joins No. 100 on the south with No. 97 on the north, close to the junction of 97 and the Lone Star fault. The triangular block thus outlined, with its extreme northern tip slightly truncated, exhibits a section extending from the top of the Golconda limestone, which is exposed in the creek bed at and above Hill Spring, through the Hardinsburg sandstone, the Glen Dean limestone, and into the Tar Springs sandstone.

Faults Nos. 102 and 103. The block lying east of fault No. 101 is traversed by two faults. No. 102 is a short cross fault cutting off a small triangular block of Palestine sandstone at the point lying between faults 97 and 101, which is dropped down relative to the mass east of the fault. Fault 103 is subparallel with No. 100. It originates at fault 101 and passes eastward, crossing the eastern boundary of the Cave in Rock quadrangle; the narrow block between it and fault No. 100 is composed of Menard limestone and Palestine sandstone, and is dropped downward relative to the larger block to the north.

In the larger block, bounded by faults 103, 101, 102, 97 and the Midway fault, which continues eastward into the Providence quadrangle, the lowest bed exposed is the summit of the Tar Springs sandstone. Above this, in the hillside east of the creek, the Vienna and Waltersburg are exposed, and above these the Menard limestone occupies a belt along the westerly facing hillside, extending all the way from fault No. 103 to No. 97. The top of the hill is capped with Palestine sandstone dipping to the north.

Fault No. 104. This fault, with a direction of about north 72° east, crosses the southeastern corner of the Cave in Rock quadrangle and has no connection with any other faults within the quadrangle, but a short distance southwest of where it crosses the southern boundary, the Lone Star fault forms a junction with it. The block between Nos. 104 and 100 lying east of the Lone Star fault, is occupied through most of its extent, by the Tar Springs sandstone, but in the bottoms of the valleys and upon the lower hill slopes, both to the north and the south, there are exposures of Glen Dean limestone. The largest exhibition of the Glen Dean is near the southwestern corner of the block.

Fault No. 105. This fault diverges from No. 104 at a point near the eastern boundary of the quadrangle, and extends in a southwesterly direction. At the southern boundary of the quadrangle it becomes essentially parallel with 104, and lies less than one-fourth of a mile to the south of it. Between the two faults there is a belt of Tar Springs sandstone which is downdropped relative to the block to the north.

Fault No. 106. This is a third fault sub-parallel with Nos. 105 and 104, and like those it continues eastward into the Providence quadrangle and southwestward into the Eddyville quadrangle. It crosses the extreme southeastern corner of the Cave in Rock quadrangle. The strip between faults 105 and 106, about one-fourth mile in width, consists of Menard limestone overlain by the Palestine sandstone, being downdropped relative to the belt to the north. South of fault 106, the small triangular area in the extreme corner of the quadrangle is Kinkaid limestone, which again is downdropped against the beds to the north.

Fault No. 107. This is a short cross fault extending diagonally between faults 105 and 106 in a northwest-southeast direction, the connection with fault 106 on the south being beyond the limits of the quadrangle to the east. The block east of the fault is a sandstone, probably Palestine, which is dropped downward relative to the block southwest of the fault.

* * *

THE ELM LICK COAL BED

BY
James H. Gardner
Assistant Geologist

LETTER OF TRANSMISSION

Dr. Willard R. Jillson,
State Geologist,
Frankfort, Ky.

Dear Sir:

Herewith I am mailing to you a copy of my report and map on the Elm Lick Coal Bed, field work on which was done by me assisted by K. D. White and Lucian Walker in 1911. The report, with a more complete map, was submitted to Prof. C. J. Norwood in the winter of 1911, but due to the fact that in 1912 the Geological Survey was transferred to Frankfort and a new regime came into being, the report was never issued.

The original map was lost which showed localities from one to twenty-four inclusive, but I have retained the mapping from the edge of the Hartford Quadrangle to Morgantown, which I include with the report.

Respectfully yours,

James H. Gardner,
Assistant Geologist.

Tulsa, Oklahoma,
October 14, 1924.

THE ELM LICK COAL BED.

By JAMES H. GARDNER.
Assistant Geologist.

INTRODUCTION.

The type locality of the Elm Lick coal bed is the district bordering Elm Lick Creek near Horton, Ky., on the Illinois Central Railroad in Ohio County. The bed was named in an early report by C. J. Norwood.[1]

The writer has recently prepared a report dealing with the economic resources of the Hartford Quadrangle which shows by map the outcrop line of No. 9 coal bed.[2]

In the report mentioned certain measurements and notes are given relative to the coal bed under discussion here, but a more complete study of the bed was reserved for additional field work in 1911, the results of which now appear in this report.

The Elm Lick coal bed is developed only locally. Small country mines have been opened at numerous points in order to supply the farm houses and small country stores with fuel. To some extent coal from the Tyro mine, on this bed east of Hartford, is marketed in Hartford; coal from the same horizon is mined at Aberdeen across Green River from Morgantown in Butler County.

This bed is very irregular in thickness as is shown by the measurements given further on in this report. There are certain districts however where the coal is sufficiently thick to justify rather extensive mining whenever the same may prove profitable through suitable location relative to transportation and the demand grows sufficiently to enable competition with the thicker, more persistent beds higher in the stratigraphic series and farther west in the coalfield.

Previous to the field work on which this report is based, it was not known that many of the occurrences of coal from McLean County to Morgantown were a single continuous horizon, that of the Elm Lick coal bed. It has generally been considered by the residents of this section of the State that many of the small, country mines were "outlying" patches of No. 9 coal bed. Now, however, that the Elm Lick bed has been mapped by the State Geological Survey and its line of outcrop presented herewith, it is almost a certainty that additional interest will be taken in the territory underlain with this coal, at moderate depths near the outcrop.

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[1] Norwood, C. J. "A general account of the Geology of a part of Ohio County." Ky. Geol. Survey, New Series, Vol. 5, Pt. 5, pp. 79-123. Reprinted 1884 in Vol. D. "Western Coalfield" pp. 133-177.

[2] Gardner, James H. "The Economic Geology of the Hartford Quadrangle." Ky. Geol. Survey, Bulletin No. 20, 1912.

Geographic Extension

The Elm Lick coal bed is not always of workable thickness along its outcrop and is, at places, entirely absent. Exposures are not so frequent as are desired for a complete knowledge of quantity in some districts traversed during the field work for this report. But the quantity as well as quality is amply sufficient to attract capital in thoroughly prospecting the bed in favorable localities.

There are frequent exposures which are not good enough to be reliable but which are sufficient to enable the geologist to trace the bed fairly accurately. As will be seen on the map, the coal was measured at a goodly number of points all the way across Ohio County from near Maxwell at the corner of Ohio, Daviess and McLean Counties southeastward by Beda, Horton, Renfrow, Baizetown, and Arnold to Bannock, Dexterville, Flenerville and Aberdeen in Butler County. This line of outcrop in a northwest-southeast direction is in a general way along the strike line of the rocks. The north end of this line has been turned westwardly by the influence of the Rough Creek Uplift as described under the subject "Structure."

The outcrop of No. 9 coal bed, which is extensively mined, lies west of the outcrop line of the Elm Lick coal bed and is shown in the writer's report to the State Geological Survey on the resources of the Hartford Quadrangle. No. 9 coal is mined on a large scale at Taylor Mines, McHenry, Williams, Simmons, Echols and Rockport. For a description of No. 9 coal and related beds of this region, the reader is referred to a report to the State Geological Survey by the writer, Bulletin No. 20.

North of the Rough Creek Uplift, the Elm Lick coal bed disappears except for thin traces at this horizon northward toward Deanefield and near Fordsville, north of the territory here mapped. The coal mined at Deanefield and Fordsville is a lower bed than the Elm Lick and is at the horizon of the Hamlin coal of the writer's section in Ohio County within the territory of the Hartford Quadrangle. It is probable that the Hamlin bed is at the same horizon as the cannel coal bed once described by C. J. Norwood in Breckenridge County. Coal at this position occurs over a wide area in Daviess County eastward from Owensboro. In this connection it is interesting to note the presence of a 5-foot bed of cannel slate, at the horizon of the Hamlin coal, near Bannock, location No. 37 on the map.

South of the Rough Creek Uplift, the Elm Lick coal bed forms a meandering line of outcrop from Barnett's Creek to Aberdeen. Eastward and southward from Aberdeen the bed disappears but may reappear farther on around the southern margin of the western coalfield. On the map, the dotted line northeastward and southward from Aberdeen indicates the absence of coal at the horizon of the Elm Lick bed. A portion of this line north of the river is only provisionally located.

Stratigraphic Position

The Elm Lick coal bed is low in the stratigraphic series. From fossils collected by the writer and submitted to Dr. David White the latter does not hesitate to refer the bed to the Pottsville group. In this opinion the writer concurs since it agrees with conclusions drawn in the field from a study of the lithologic character and physiographic record of the sedimentation.

A massive, coarse-grained sandstone containing flakes of mica (muscovite) lies usually a slight distance above the Elm Lick bed. It is sometimes on the bed or even rests on rocks below the coal. It is decidedly unconformable, cross-bedded and contains fragments of silicified wood. This sandstone is persistent over the entire area mapped and possibly encircles the entire coal field. K. D. White reports that a heavy sandstone above No. 5 coal bed of Dr. Glenn's section in Webster County is likely the same sandstone, in which case No. 5 coal of that section corresponds to the Elm Lick coal. This heavy, micaceous sandstone is in all likelihood the top of the Pottsville in the western Kentucky coalfield. It contrasts in composition and character with the beds above it but falls into the class of rocks below which are now known to be Pottsville from fossils collected by the writer from the roof of the Elm Lick bed. The prominent sandstone referred to is here named the Aberdeen sandstone, the type locality being the town of Aberdeen near Morgantown in Butler County, where the sandstone stands out in prominent, well-defined cliffs along Green River.

The following section from the Chester, or Kaskaskia, limestone up to No. 9 coal will show the relative position of the Elm Lick bed:

Section showing position of the Elm Lick bed.

	Ft.	In.
No. 9 Coal	4	4
Under-clay	3	..
Shale containing ferro-calcareous concretions and local beds of soft sandstone	50	..
Shale, bituminous, dark	3	..
Goshen Coal	1	3
Shale and some sandstone	15	..
Limestone, dense, gray, weathers yellowish	2	..
Shale and sandstone	10	..
Shale, bituminous, dark	1	6
Schultztown Coal	1	3
Under-clay, plastic, gray	3	..
Sandstone, soft, gray, weathers brown	32	..
Shale, dark, bituminous	1	6
Beaver Dam Coal	1	..
Under-clay, plastic, gray	3	..
Limestone, dense, gray, often nodular or cherty	2	..
Sandstone and shale, local coal streak	50	..
Sandstone, massive, gray	5	..
Shale, drab-colored, local coal streak	15	..
Shale	2	..
Shale, dark, bituminous	1	6
Hartford Coal	1	6
Sandstone and shale	75	..
Shale	5	..
Limestone, bluish	1	6
Shale, thin limestone locally present	3	10
Millsite Coal	..	8
Under-clay, plastic, gray	2	6
Shale and some sandstone	8	..
"Fusulina Chert"	..	6
Shale and sandstone	20	..

Section showing position of the Elm Lick Bed.—Continued.

	Ft.	In.
Limestone, occurring only locally	1	..
Beda Coal	1	5
Under-clay, gray, plastic	10	..
Aberdeen Sandstone, massive, coarse, micaceous	25	..
(Unconformity)		
Coal, thin, usually cut out by unconformity	..	6
Shale, drab-colored	11	..
Sandstone, thin-bedded, soft, local	7	..
Elm Lick Coal	2	6
Under-clay, variable	1	..
Shale, gray, sandy, dark when fresh	50	..
Hamlin Coal	2	..
Shale, gray, sandy, dark when fresh	25	..
Shale, thin-bedded sandstone and limonite	19	..
Conglomeritic Sandstone, absent.		
Chester.		

In the above section, the seventy-five feet of shale which holds the Hamlin coal constitutes the "Deanefield Shale" which runs throughout the whole territory from Butler to Daviess Counties and is widely exposed around Deanefield and Fordsville. It forms the surface rocks, capped by the Aberdeen sandstone, over a large portion of the Whitesville and Owensboro quadrangles.

STRUCTURE.

The main structural feature influencing the Elm Lick coal bed is the Rough Creek Uplift. Within the area of the accompanying map this structure has the form of a fault zone with an upthrow on the south side. The throw, or vertical displacement of the rocks, along the fault zone is a variable quantity between 600 feet on the west side to more than 1,000 feet along Clear Run. On the north side of the zone, the rocks have a dip nearly normal to the coal basin; but on the south, or upthrow side, the rocks are folded in an irregular anticline with minor parallel folds to the southward.

A vast amount of erosion has taken place since the time of the Rough Creek disturbance. A sufficient amount in fact to justify placing the time of disturbance back as far as the close of the Cretaceous system. There is an offset of eight miles in the outcrop of the Elm Lick coal bed from near Clear Run Church nearly to the McLean County line. This offset along the fault is due to the large uplift on the south and subsequent erosion. From Mt. Vernon Church westward, north of Beda to Barnett's Creek, the Elm Lick coal bed is entirely eroded. At one time the rocks along this line stood as a high escarpment facing northward; but erosion has truncated this escarpment to the level of the surrounding topography. Such has not been the case, however, at the spur fault crossing Barnett's Creek at the "Backbone Ridge." At the latter point, the upthrow side still stands as an escarpment, making the ridge.

All the high points in this section of Kentucky rise to an even sky-line regardless of the horizon of the rocks; this indicates that the region has been peneplaned. It is probable that at the time the Lafayette formation was being deposited in the Mississippi Valley this region showed very slight relief and was not high above tide level. For three or four miles back in the highlands on either side of Green River there are beds of old stream gravels; at Morgantown in Butler County these beds are 134 feet above low-water level. The presence of these gravels far above the present stream shows that erosion has gone on rather rapidly here in modern geologic time. The present relief represents a distinct cycle of erosion.

Between Rough River and Morgantown the Elm Lick coal bed is nearly horizontal except for very local variations of a few degrees in amount and direction of dip. The crooked line of outcrop, with outlying patches shown on the map, indicates the level monotony of the strata. Note on the map how the outcrop running southward from Renfrow along the west side of North Fork swings back at the mouth of Sixes Creek and follows up the latter almost cutting through and disconnecting the field between the two creeks. Throughout this region the coal is low to drainage with rarely as much as 100 feet of cover on the divides.

A structure worthy of note is the unconformity at the base of the Aberdeen sandstone which lies above the Elm Lick coal and which likely marks the top of the Pottsville group. This sandstone often rests on lower beds than the next oldest rocks. A period of erosion existed previous to the deposition of this sandstone, so that it is brought down upon an old surface. The indications of such an old surface as well as the wavy line of contact at the base of the sandstone are shown at various points but typically so along the wagon road leading down to the east ferry at Morgantown. At this point the sandstone rests on rocks below the horizon of the Elm Lick coal. The rocks on which it rests belong to what may with propriety be called the Deanefield shale which holds the Hamlin coal bed. When fresh, it is very dark, sandy clay shale but usually it is seen in outcrop, long weathered and bleached, and is brownish-gray in color. The corrasion of Green River keeps it clean and fresh at the ferry landing where its dark color due to carbonaceous material is very noticeable. The same shale bed is shown in a cut on the new M. H. & E. Railroad just south of Sunnydale and north of the fault zone; its very dark color when fresh is again well shown here; when fresh, it resembles Devonian shale. This is a very persistent bed; it crosses Ohio County and is undoubtedly widely exposed in Butler County. It lies nearly level over a large portion of the Whitesville quadrangle and extends to the Ohio River. Within this shale, is the Hamlin coal named from Hamlin Chapel northeast of Hartford and mined at Deanefield and Fordsville, north of the accompanying map. A thin coal at the Hamlin coal horizon shows in the Deanefield shale at the east ferry near Morgantown to which reference has been made.

In the mining of the Elm Lick coal at Aberdeen, considerable trouble has been encountered by the coal being cut out by the Aberdeen sandstone. This sandstone is typically exposed at the Aberdeen ferry. It rests on the coal there and at places rests on the floor of the coal bed, or in other words takes the place of the coal. Eastward and northeastward from Aberdeen, it cuts out the coal entirely, judging from what can be seen around the outcrop of the sandstone. This same condition is true in the territory north of the Rough Creek Uplift and probably all over the north part of the Whitesville topographic sheet.

Measurements and Quality.

On the map the writer has placed a continuous series of numbers each enclosed by a circle in order to readily catch the reader's eye. These numbers read from the top of the map downward; they signify cross-reference to corresponding numbers in the text where notes are given on the sections and character of the coal. These points are very accurately located on the map and the outcrop of the bed is in considerable detail; the outcrop line will stand an enlargement of several diameters and can still be depended on for detail if any person desires to use any portion of it on a larger scale.

LOCATIONS NO. 1 AND NO. 2.

(Near Clear Run Church.)

North of the Rough Creek Uplift, the Elm Lick coal is absent except for thin traces of coal in certain districts. However, the typical Aberdeen sandstone and underlying Deanefield shale are exposed in characteristic outcrop over the region between Union Grove and Clear Run Churches. At Locations No. 1 and No. 2, there are good, clear exposures of the sandstone resting on the shale with no signs of coal. At a point farther northward near Adaburg on the farm of T. W. Wedding, the coal appears at the regular Elm Lick horizon showing a thickness of eleven inches. Above it, there is a typical exposure of the Aberdeen sandstone, 25 feet of which stands in a massive cliff. Between the sandstone and the coal there is a bed of shale 10 feet thick which indicates that the coal has its original thickness here and has not been affected by the erosion previous to the deposition of the unconformable Aberdeen sandstone.

LOCATION NO. 3.

(Barnett's Creek, one mile southwest of Old Salt Wells.)

At Location No. 3, an entry was once made into the Elm Lick coal on the farm of H. F. Tucker. In 1911 this prospect was entirely filled by falling of the roof, etc. It has been abandoned for some years. On reliable authority, the coal is 28 inches thick at this point. In the hill above the coal, there are exposures of the Aberdeen sandstone. Pieces of coal on the dump present the usual characteristic appearance of the Elm Lick coal. This location is south of the main fault zone but north of the spur fault which makes the "Backbone Ridge."

The throw of this fault is about 120 feet. The upthrow side, on the south, has not been eroded from Barnett's Creek westward along the strike to the main fault zone, but stands as a sharp ridge known locally as the Backbone Ridge and so labelled on the Sutherland Sheet.

LOCATIONS NO. 4 AND NO. 5.

(Just west of Barnett's Creek, 2 miles west of Chapman School.)

The Elm Lick coal bed is not exposed at these points but the next higher coal, the Beda, has been opened at the two places indicated. The bed is 14 inches thick and contains in this locality, a limestone roof. Beneath it, the Aberdeen sandstone which overlies the Elm Lick bed, shows characteristic exposures.

LOCATION NO. 6.

(One-half mile south of Chapman School.)

At Location No. 6 on the farm of J. B. Rowan, there are poor exposures of the Elm Lick coal bed beneath the Aberdeen sandstone. K. D. White reports the coal less than 2 feet thick showing alternate layers of hard, tarry coal with layers of soft carbon or mother-of-coal.

LOCATION NO. 7.

(One-half mile northwest of Beda.)

On the farm of W. C. Ambrose, at Location No. 7, the Elm Lick coal bed is exposed showing a thickness of eighteen inches.

LOCATION NO. 8.

(One-half mile southeast of Beda.)

On a branch of No Creek at Location No. 8, the Elm Lick coal bed was opened many years ago. The opening is now filled but the coal is poorly exposed in the side of the creek bed showing about 30 inches of coal. Mr. W. Parks of Beda, states that the coal in the mine showed as much as 3 feet as some points, but its minable thickness was very local. A few hundred yards from this point, the bed is less than 18 inches thick.

LOCATION NO. 9.

(Two miles northeast of Beda.)

At Location No. 9 on property owned by John Herald and James Everling, there is a small mine known as the Murray mine, which is operated to supply the country market. The following is a section at the mine:

Section at Herald-Everling Mine.

	Ft.	In.
Covered		
Sandy shale roof.		
Coal	2	6
Shale.		

This coal is reported to be very popular for fuel. The bed shows considerable joint structure across the bedding. Along the bedding planes there are characteristic black, tarry layers which are high in volatile matter. The coal is easily kindled.

LOCATION NO. 10.

(Three and a half miles north of Hartford.)

At Location No. 10 on the farm of Isaac Shown, a small prospect has been made in the coal but at the time of the writer's visit, the bed was only partly exposed beneath a heavy ledge of sandy shale. Mr. Shown reports 30 inches of coal here of splendid quality. The coal shows the characteristic tarry layers alternating with layers of soft carbon along the bedding planes.

LOCATION NO. 11.

(Three miles east of Hartford.)

Location No. 11 is the R. P. Tyro mine. Considerable coal is mined here for the market in Hartford and surrounding country. This mine and the one at Aberdeen are the two largest mines on the Elm Lick coal. The other small mines are operated only to secure fuel for farm houses in winter. The coal is above the average in thickness at the Tyro and Aberdeen mines, together with the fact of their having better market demands. The following is the section at the Tyro mine.

Section at R. P. Tyro Mine.

	Ft.	In.
Shale, sandy		
Shale, carbonaceous, black	3	10
Coal, soft, blocky		10
Clay, hard		5½
Coal, hard	2	10
Shale, gray-clay.		

The Tyro coal has a good name as a fuel coal and competes well with No. 9 coal when all other things are equal. The following is the analysis of the coal by J. S. McHargue, Survey Chemist, made from a sample collected by Lucian Walker under the writer's directions.

Analysis of coal from R. P. Tyro Mine.
Air Dried Sample.

	Per Cent.
Moisture	5.37
Volatile combustible matter	32.64
Fixed carbon	39.91
Ash (reddish)	22.08
	100.00
Sulphur	3.72
Coke, dense, cells small	61.91

LOCATION NO. 12.

(One-half mile northeast of Tyro mine.)

On the farm of Fred Tatum at Location No. 12, K. D. White reports that the Elm Lick coal was discovered at the bottom of a well which is 23 feet deep. The thickness is uncertain.

LOCATION NO. 13.

(One and a half miles east of north of Tyro mine.)

The Elm Lick coal has been opened on the farm of E. M. Daniels, at Location No. 13. K. D. White visited the mine here and reports a thickness of 5 feet with a parting one-half inch thick, twenty inches from the top. Beneath the parting, the coal is thinly laminated. The roof is shale.

LOCATION NO. 14.

(One and one-quarter miles southeast of Tyro mine.)

In the bed of a branch at Location No. 14, the Elm Lick coal shows in poor exposure with the thickness undetermined.

LOCATION NO. 15.

(Four miles northeast of Beaverdam.)

There are two small openings at Location No. 15. The one on the north is the Henry Tinsley (colored) mine and the one on the south is the B. H. Howard mine. The coal is practically the same at the two places. At each place the roof is sandstone. The following is the section at the Tinsley mine:

Section at Tinsley Mine.

	Ft.	In.
Sandstone	4+	.
Coal	1	1½
Clay, gray, indurated	.	6
Coal	2	9
Shale, gray.		

A section could not be secured in detail at the Howard mine, but from all reports and appearances the two sections are similar. The Howard mine was filled with water near the entrance at the time of the field work. Both mines were closed down at that time.

LOCATION NO. 16.

(One and one-half miles northeast of Beaverdam.)

At Location No. 16, on the north side of Muddy Creek, near the Hartford road, the Elm Lick coal shows in natural outcrop beneath the Aberdeen sandstone with 8 feet of intervening shale of bluish-gray color. The outcrop indicates about 3 feet of coal and clay and is sufficient to justify further examination in this locality by prospectors.

LOCATION NO. 17.

(Two miles northeast of Beaverdam.)

Location No. 17 is the small opening on the farm of John

Chinn. It is not operated as a mine and was filled with water and debris during the field work for this report. Mr. Chinn reported the following section here:

Section at Chinn prospect.

	Ft.	In.
Shale		
Coal	1	6
Clay, gray, indurated	.	4
Coal	4	2
Shale, gray.		

LOCATION NO. 18.

(One and one-half miles southwest of Horton.)

At Location No. 18, an opening was once made into the coal on the farm of Marion Sandifur, but is now filled. In the south bank of Muddy Creek, near the old opening, the coal shows a thickness of about two feet.

LOCATION NO. 19.

(One mile east of south of Horton.)

A small country mine has been opened at Location No. 19 on the farm of R. P. Leach. The entry was to a depth of about 30 feet in 1911. The following is a section in the mine:

Section in R. P. Leach Mine.

	Ft.	In.
Shale, gray	5	..
Coal and shale	.	5
Coal, blocky	.	10
Clay, gray, indurated	2	..
Coal	3	2
Shale, hard.		

The coal in the Leach mine, below the clay, is hard and splinty in character. Along the bedding planes it shows the usual tarry patches alternating with layers of soft carbon.

LOCATION NO. 20.

(One quarter mile northeast of Hickory Church.)

On the farm of R. C. Jarnogin, at Location No. 20, an opening was recently made into the Elm Lick coal by Henry Isler. The coal shows the following section:

Section at Jarnogin opening.

	Ft.	In.
Massive sandstone; top shows 50 feet above coal.		
Sandy shale roof.		
Coal	1	4
Clay	.	$\frac{1}{2}$
Coal	1	6

LOCATION NO. 21.

(One mile northeast of Hickory Church.)

At Location No. 21, the Elm Lick coal is indicated by the presence of copperas water flowing from a small spring. Mr. H. N. Plummer reported that coal is found here 6 feet below the surface, but the thickness has not been determined.

LOCATION NO. 22.

(Near Bald Knob Church.)

Along Threelick Creek, northwest of Bald Knob Church, the Elm Lick coal bed has been cut out by erosion so that the horizon lies slightly above drainage level on either side of the creek. There are no good exposures of the coal around this inlier but on the Payton place, one-quarter mile northwest of the church, the coal is reported to be of workable thickness in an opening made many years ago and now completely filled. One mile northwest of the church, a poor outcrop of the coal shows near the Beaverdam road.

LOCATION NO. 23.

(One mile northeast of Bald Knob Church.)

At Location No. 23, on the Clay Taylor place, the Elm Lick coal is 3 feet and 6 inches thick with a thin parting 20 inches from the top. The roof at this point is clay shale.

LOCATION NO. 24.

(One-quarter mile west of Mt. Pleasant Church.)

West of Mt. Pleasant Church there are indications of the Elm Lick coal around the outcrop. The Aberdeen sandstone has very characteristic exposures in this vicinity. There are signs of old openings on the coal beneath the sandstone but no reliable section could be secured to show the thickness and character of the coal at this particular point. At Location No. 24 there is an old opening showing coal waste. Weathered outcrops indicate that the coal is at least two feet thick.

LOCATION NO. 25.

(One mile east of Mt. Pleasant Church.)

Location No. 25 is on the place of J. H. Baize. The Elm Lick coal bed here shows the following section in a small gully where some stripping has been done by Mr. Baize:

Section on place of J. H. Baize.

Covered	Ft.	In.
Clay shale	.	8
Coal, splinty	1	6
Coal, blocky	.	10
Under-clay	3	..
Covered		

An analysis of the coal, more or less weathered, as made by J. S. McHargue, is as follows:

Analysis of coal from place of J. H. Baize.

Air Dried Sample.

	Per Cent.
Moisture	7.58
Volatile combustible matter	36.62
Fixed carbon	52.36
Ash (brown)	3.44
	100.00
Sulphur	1.26
Coke, friable, cells small	55.80

LOCATION NO. 26.

(One mile southwest of Rosine.)

Location No. 26 is a local mine owned and operated by the Monroe Brothers. Considerable coal is mined here for local market in the country. The lower 34 inches of clear coal is mined; the writer is not familiar with the section above this portion of the bed, as the surface rocks were not exposed at this point. The coal has a good reputation as a fuel coal; it presents the characteristic appearance of the Elm Lick coal, consisting of layers of tarry patches along the bedding planes which alternate with splinty coal and layers high in soft carbon. It kindles readily due to the highly volatile layers. The area of workable coal at this point is very limited as will be seen from the small area shown to proper scale on the map.

LOCATION NO. 27.

(One and one-half miles southeast of Mt. Pleasant Church.)

The William Allen mine is shown at Location No. 27. The Elm Lick coal is 18 inches thick at this point but has the reputation of being the best blacksmithing coal in the territory; it is also very excellent fuel for grates. It is mined to a very limited extent for the local market. The following is the analysis of this coal as made by J. S. McHargue:

Analysis of coal from the William Allen Mine.
Air Dried Sample.

	Per Cent.
Moisture	7.40
Volatile combustible matter	38.73
Fixed carbon	51.24
Ash (yellow)	2.63
	100.00
Sulphur	0.83
Coke, good cells medium size	53.87

LOCATION NO. 28.

(Near head of Sixes Creek.)

A prospect at Location No. 28 was made several years ago in the Elm Lick coal by Frank Daugherty. Coal for local use was mined here but at the time of the writer's visit no section could be secured on account of the prospect being completely filled. Loose pieces of coal showed on the old dump. Along Sixes Creek at this point, there are characteristic exposures of the Aberdeen sandstone which lies just above the coal.

LOCATION NO. 29.

(One-quarter mile southeast of Renfrow.)

Around Renfrow the Elm Lick coal bed was noted; at location No. 29 the bed outcrops as a very prominent black band across the road leading to Arnold. The same bed was encountered in the water well of L. N. Worley in Renfrow at a depth of 20 feet; the bed was reported by Mr. Worley to be 34 inches thick with a sandy shale roof. J. T. Renfrow, of the same place, states that the bed was struck in his well but he does not recall the depth nor thickness.

One and a half miles north of Renfrow and south of Horse Branch, the Hamlin coal is 17 inches thick on the farm of Callie Cowan.

LOCATION NO. 30.

(One and a half miles north of Baizetown.)

Location No. 30 is the R. P. Daugherty mine which shows the Elm Lick coal of rather unusual thickness; the coal is 39 inches thick here and shows 8 feet of sandy shale as a roof. The bed is made up of rather thin laminations along the bedding. The following analysis of the coal by J. S. McHargue will give an idea of the nature of the coal as a fuel:

Analysis of coal from R. P. Daugherty Mine.

Air Dried Sample.	Per Cent.
Moisture	7.61
Volatile combustible matter	36.84
Fixed carbon	52.67
Ash (red)	2.88
	100.00
Sulphur	1.32
Coke, rather dense, cells small	55.55

The same bed has been opened a few hundred yards around the hill to the southeast of this point and near the dwelling of Mr. Daugherty. It maintains its thickness in this distance.

LOCATION NO. 31.

(One mile north of Baizetown.)

A local mine on the Elm Lick coal bed at Location No. 31, is on the farm of George Baize. The coal is 33 inches thick with gray shale roof and gray under-clay. The following is the analysis of this coal from an average sample: the analysis was made by J. S. McHargue.

Analysis of coal from the George Baize Mine.
Air Dried Sample.

	Per Cent.
Moisture	6.90
Volatile combustible matter	37.56
Fixed carbon	51.46
Ash (reddish)	4.08
	100.00
Sulphur	1.30
Coke, friable, cells small	55.54

LOCATION NO. 32.

(One mile north of east of Baizetown.)

Location No. 32 is the Lafe Emery mine near the road from Baizetown to Arnold. A shallow prospect has been made in the Elm Lick coal at this point showing the following section:

Section at Lafe Emery prospect.

	Ft.	In.
Shale, dark gray	8	..
Coal	.	3
Shale, gray	.	10
Coal	3	..
Shale, dark, hard	6	..
Shale, gray.		

At the Lafe Emery place the Elm Lick coal is very low to the drainage of Sixes Creek, due to a slight syncline in the structure.

LOCATION NO. 33.

(One-half mile southeast of Baizetown.)

On the farm of E. D. Wilkerson at Location No. 33 the Elm Lick coal shows the following thickness as given in the section by K. D. White.

Section at Wilkerson Mine.

	Ft.	In.
Sandstone, massive (Aberdeen)	15	..
Shale, sandy	10	..
Shale, gray, hard	4	..
Coal	2	6
Covered.		

The Wilkerson coal is reported to be excellent for blacksmithing purposes and is so used at local shops.

LOCATION NO. 34.

(One and three-quarter miles southeast of Baizetown.)

A local opening at Location No. 34 was once made into the coal on the farm of Robert Cook. The Elm Lick coal is reported 40 inches thick here with a thin clay parting 6 inches from the top and a second parting 18 inches from the top. At the time of field work the opening was completely filled.

LOCATION NO. 35.

(One and one-quarter miles south of Arnold.)

At Location No. 35 a prospect was made by Henry Daugherty some years ago on his farm. The Elm Lick coal is 29 inches thick here with 9 feet of dark shale between it and the overlying Aberdeen sandstone.

LOCATION NO. 36.

(One mile north of Dexterville.)

The Elm Lick coal has been opened at Location No. 36 on the farm of Archie Moore. The coal is 26 inches thick at this point and is covered by 10 feet of gray shale.

LOCATION NO. 37.

(Three-quarters of a mile east of Bannock.)

The Hamlin coal below the Elm Lick bed is represented at Location No. 37 by a 5-foot bed of black cannel slate, on the farm of Ben F. Morris. The slate has a typical cannel appearance, a conchoidal fracture, and burns freely for a short time, leaving a mass of gray slate. This occurrence is interesting in connection with the extension and character of this coal horizon. The Hamlin coal in northern Ohio County often contains streaks of cannel coal as shown in the mines near Deanfield and it is highly probable that the cannel coal of the Breckenridge cannel coal district, once described by C. J. Norwood in a report to the State Geological Survey, is at this same horizon.

LOCATION NO. 38.

(One mile north of Flenerville.)

At Location No. 38 a local opening has been made in the Elm Lick coal on the farm of Cornelius Felty. The coal is 30 inches thick with a shale roof and clay floor.

A short distance to the northwest the bed has been opened showing the same thickness on the farm of John Flener. The following is the analysis of J. S. McHargue of the Flener coal from an average sample collected by the writer:

Analysis of coal from the John Flener Mine.

Air Dried Sample.	Per Cent.
Moisture	5.85
Volatile combustible matter	37.65
Fixed carbon	46.41
Ash (brown)	10.09
	100.00
Sulphur	2.21
Coke, rather dense, cells small	56.50

LOCATION NO. 39.

(One-half mile northwest of Flenerville.)

A prospect on the farm of Owen Flener at Location No. 29

and another a short distance to the southwest of the farm of Luke Flener show the Elm Lick coal bed 24 inches thick with a shale roof and clay floor.

LOCATION NO. 40.

(One and a quarter miles southwest of Flenerville.)

On the farm of John W. Deweese at Location No. 40, the Elm Lick coal bed shows a thickness of 32 inches with a shale roof. A short entry has been made into the bed at this point. The coal is reported a good fuel coal at this mine and at the others around Flenerville.

LOCATION NO. 41.

(One-quarter mile south of Flenerville.)

At Location No. 41, one-quarter mile south of Flenerville, the Elm Lick Coal has been opened at what is known as the Smith bank. No section could be secured here but the coal is reported to show the usual thickness around Flenerville as shown in preceding sections. Above the coal there are typical exposures of the soft, coarse-grained Aberdeen sandstone which outcrops along the Morgantown road at this point.

LOCATION NO. 42.

(Aberdeen.)

Between Location No. 41 and Location No. 42 the Elm Lick coal bed does not outcrop. To the eastward, the coal is cut out by the unconformity at the base of the Aberdeen sandstone. The dotted line on the map indicates the approximate boundary of the territory beyond which the coal apparently does not occur.

Location No. 42 is the Aberdeen mine owned at the time of field work, by the Guntry Grocery Company of Owensboro, successors of the Aberdeen Coal Company. The coal was opened at one time near the Aberdeen ferry a short distance northwest of the present opening. The bed has proved somewhat treacherous at this point, on account of the unconformity at the base of the Aberdeen sandstone. This sandstone stands out as a prominent cliff on the bank of Green River near the Aberdeen ferry. It has been referred to throughout this report as the Aberdeen sandstone, this being the type locality. In the workings of the Aberdeen mine, this sandstone comes down at places to the floor of the coal completely taking the place of the bed. Where the coal shows its natural thickness it is covered by shale in the mine and is 44 inches thick, divided into two beds of coal with no parting or with what has been called a "smooth parting." The upper bed is 17 inches thick and is rather thinly laminated whereas the lower 27 inches is massive, or blocky, in nature. From an average sample of the coal, the following analysis was made by J. S. McHargue:

Analysis of Elm Lick coal from Aberdeen Mine.

Air Dried Sample.

	Per Cent.
Moisture	5.47
Volatile combustible matter	36.71
Fixed carbon	44.40
Ash (brown)	13.42
	100.00
Sulphur	2.08
Coke, dense, cells small	57.82

LOCATION NO. 43.

(East Ferry at Morgantown.)

In the south banks of Green River at the east ferry at Morgantown, the Aberdeen sandstone stands out as a bold cliff and a clear section was secured from the top of this formation down to the level of Green River at low water.

The Elm Lick coal is entirely gone at this point and the unconformity at the base of the Aberdeen sandstone is very evident. Typical exposures of the Deanefield shale which includes the Hamlin coal show along the river bank. The following is a detailed stratigraphic section from the water level at the ferry up to the top of the river bluff as made by the writer, assisted by Lucian Walker:

Section of rocks at East Ferry, Morgantown, Ky.

	Ft.	In.
Sandstone alternating with shale	18	..
Aberdeen sandstone, massive, coarse-grained, micaceous, cross-bedded	39	..
Old surface material; carbonaceous streaks and water-worn fragments; soft sand and clay inclusions	2	9
(Unconformity of erosion).		
Shale, gray, sandy (locally cut out)	5	6
Shale, gray, sandy	6	..
Shale, dark-colored	17	..
Siderite concretions; roundish; average 1 in. diameter	..	6
Shale, dark-colored	3	..
Shale, arenaceous, ferruginous	3	..
Hamlin coal	..	10
Under-clay	..	6
Shale, dark-colored with siderite concretions	8	6
Sandstone, thinly laminated, argillaceous	5	6
Shale, dark-colored	16	..
Shale, dark-colored with layers of siderite concretions	5	4
Lenticular layers of siderite	..	4
Shale, dark-colored with layers of siderite	6	..
Lenticular layers of siderite	..	4
Sandstone, gray, argillaceous	1	..
Green River; low water level, elevation 382.8 above tide.		
Total	138	3

In the above section all rocks are Pottsville and from the unconformity down belong to the formation designated in this report the Deanefield formation.

In the south part of Morgantown near the west road leading to the Fair Grounds, a coal bed has been exposed which lies 80 feet above the Aberdeen sandstone. It shows a thickness of 20 inches and apparently does not represent any of the coals of the writer's Ohio County section. It is here designated the Morgantown bed, its relationships to other coal beds to be determined by future geologic work in this region.

THE MUD RIVER MINES, MUHLENBERG COUNTY.

At the time of the writer's field work, a visit was made to the Mud River mines in Muhlenberg County about 5 miles west of south of Rochester. It was hoped that positive correlation might be made between this coal and some other known coal but the territory is so badly covered by forest growth that no extensive stratigraphic section could be gotten nor the outcrop traced. The following section is the best that could be obtained:

Section at Mud River Mines.

	Ft.	In.
Sandstone, massive, brown, micaceous ...	15	..
Coal	3	4
Soft powdery coal	..	2
Under-clay.		

The upper 20 inches of the coal is thin-bedded and the remainder of a bright, blocky nature. The section most assuredly resembles those made around the outcrop of the Elm Lick coal bed in Ohio and Butler Counties. The double nature of the bed is also much like the Elm Lick. Moreover the appearance of the coal itself is very similar to the Elm Lick coal. The writer presents these evidences for what they are worth believing that future work on the Rochester topographic sheet will prove the coal to be at the Elm Lick horizon. A broad study of the surrounding territory is necessary to absolutely establish the relationships.

The Mud River mines were formerly operated by the Mud River Coal, Coke and Iron Company, but they have been closed for 12 years and the branch track to the O. & N. division of the L. & N. Railroad has been torn away. The property is at present leased by Owen Hart from Mrs. Aikin of Nashville. A shallow entry supplies coal to the local country trade.

Following is an analysis of the coal, made by the Survey chemist, J. S. McHargue:

Air Dried Sample.	Per Cent.
Moisture	6.71
Volatile combustible matter	38.36
Fixed carbon	51.98
Ash (brown)	2.95
	100.00
Sulphur	0.76
Coke, friable, cells large	54.93

GEOLOGY OF THE BEREA REGION

A Study of the Topography, Geology, Climate, Soils, Mineral Resources and Water Supply of the southeastern Bluegrass and Knobs of Kentucky

BY

Wilbur Greeley Burroughs
Assistant Geologist

LETTER OF TRANSMISSION

Dr. Willard Rouse Jillson,
Director and State Geologist,
The Kentucky Geological Survey,
Frankfort, Kentucky.

Dear Sir:

Permit me to transmit herewith my manuscript and illustrations of a report on the "Geology of the Berea Region."

This report is the result of field work carried on during the six and one-half years that I have been located at Berea, Kentucky. The subjects described in detail include the geology, topography, climate, mineral resources, soils, and water resources of the southeastern Bluegrass and Knobs. The influence of these factors upon the life conditions is explained. The undeveloped mineral resources of the area are described and the industries that can successfully locate in the region and develop these mineral resources are noted. Many of the mineral deposits can be utilized by the citizens now living in the area, such as vast quantities of marl which can be spread on the fields to increase the yield of the crops.

The report has been prepared with the hope that it may be of practical value to the people of the region about Berea, and to the State.

Respectfully submitted,

Wilbur Greeley Burroughs,

Assistant Geologist.

Berea, Kentucky,
March 24, 1926.

GEOLOGY OF THE BEREA REGION

BY

WILBUR GREELEY BURROUGHS
Assistant Geologist

SITUATION.

The Berea Region is situated in east central Kentucky. It embraces that area included within a circle having a six-mile radius with Berea, Madison County, as its center. The territory, which is chiefly in Madison County, extends southward into Rockcastle County and on the southeast touches Jackson County. The town of Berea lies in north latitude 37 degrees 34 minutes, west longitude 84 degrees 17 minutes.

Geographically and geologically this area forms a part of the western margin of the Appalachian Highlands. The drainage is into the Ohio River.

LIFE CONDITIONS.

Berea is the principal town. It is built chiefly upon the flat top and sloping sides of a ridge which in past ages formed part of a plain extending across the Bluegrass of Kentucky. The view from the majority of the streets is very fine. From the northeast southward to southwest stretches rugged knob topography. In other directions gently undulating land meets the horizon. The elevated location of the town also affords an excellent atmosphere and good drainage.

Commercially Berea has an advantageous position. Three miles to the south is Boone's Gap. In pioneer days a branch of the Wilderness Road extended through this pass, and continuing northward crossed the present site of Berea. In modern times Berea is served by the Cincinnati-Knoxville Division of the Louisville & Nashville Railroad. At the Gap the railroad goes through a tunnel which has been driven through the knob. The Dixie Highway also connects Berea with other portions of Kentucky and nearby States. Wagon roads radiate out in all directions from the town. Thus Berea is a trade center for a considerable territory in the Mountains, Knobs and Bluegrass.

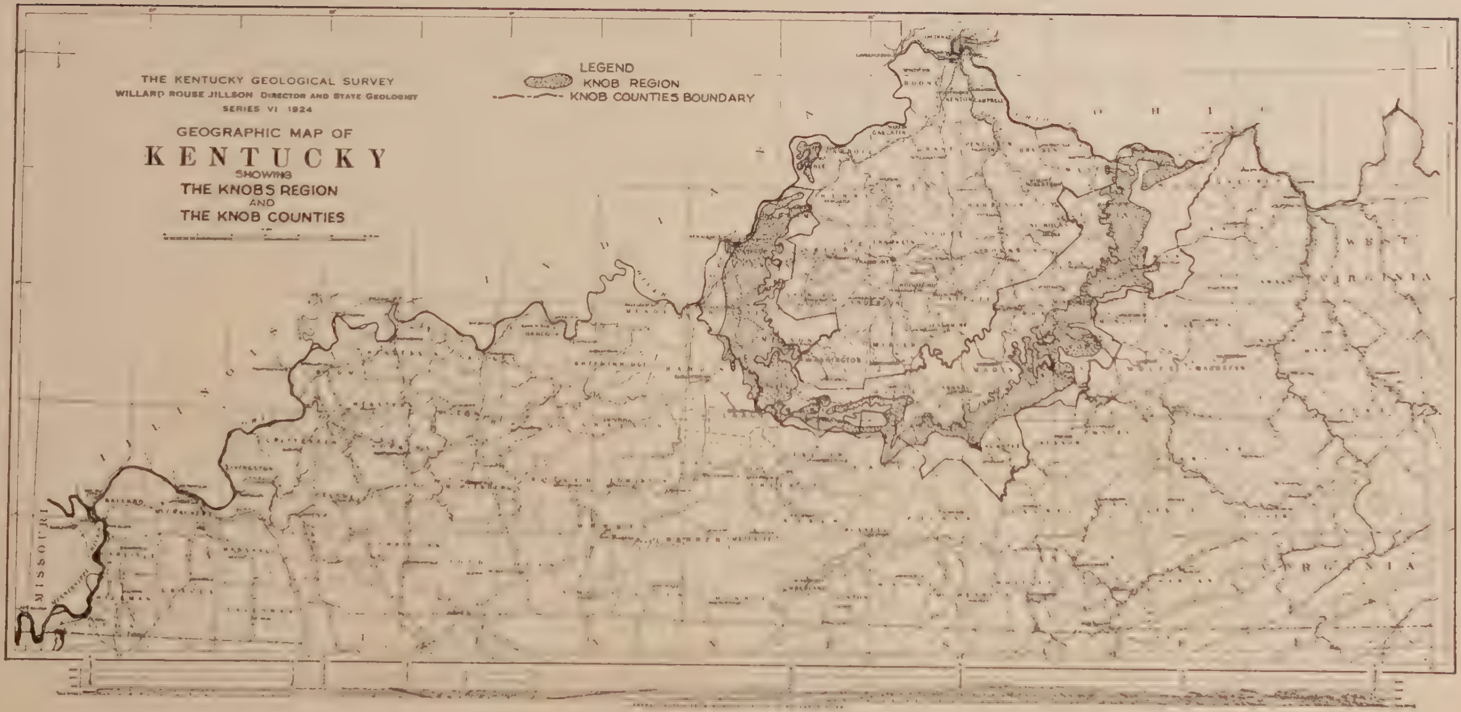

Plate I. MAP OF KENTUCKY, SHOWING THE KNOBS REGION.

A belt of dissected, surficial Mississippian strata occurs east of the stippled area in Lewis County and to the Kentucky Mountains in Rowan and counties southward. In Trimble County the stippled area is entirely Silurian strata. The Berea Region is near where the Louisville & Nashville Railroad cuts the Knob Belt, in Madison County.

The chief activity of the town is Berea College and Allied Schools, whose total enrollment is about 2,700 students, including summer school pupils. Industrial enterprises in Berea include a grist mill, planing mill, and four establishments where hand-woven goods are made. The town is supplied with electricity furnished by the College power plant. There is a system of water-works and sewerage disposal. The streets are macadamized, and kept in good condition. Several fine churches, numerous handsome residences, and excellent College buildings make Berea a beautiful town.

The population of Berea is steadily increasing. In 1900 there were 762 residents; in 1920, 1,510. With a minimum of 2,000 students throughout the college year, the total population is 3,510.

Plate II. BOONE'S GAP.

A monument marking Boone's Trail is shown on the left. In the distance the Louisville & Nashville Railroad track stretches southward. At the Gap the railroad passes through a tunnel in the knob.

Outside of the town of Berea, the region contains the villages of Kingston and Wallaceton. There are also a few houses and a store or two at several of the cross-roads. Such local trading centers are Bobtown, Middletown, Big Hill and Boone's Gap.

Agriculture is the principal occupation outside of the towns. The chief crop is corn. Oats and other cereals are raised to a lesser extent. Tobacco is grown. Orchard and small fruits are grown for individual farm use. On the hills south of the Madison-Rockcastle County line, several large peach orchards have been planted. The College has extensive truck gardens. Livestock are raised and fattened, and dairy cattle are kept in the Berea Region. Poultry and occasionally bees are kept on the farms. Lumbering is one of the lesser occupations. Coal mining is carried on in small, drift mines near the top of Big Hill. Limestone is quarried occasionally for road metal.

CLIMATE.

The climate of the Berea Region is shown in the following tables prepared by the United States Weather Bureau. All observations here given were taken at Berea.[1]

EXPOSURE OF DEVONIAN OIL SHALE

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[1] For additional weather records see Burroughs, W. G., Geography of the Kentucky Knobs; Ky. Geol. Survey, Series VI, Vol. 19, pp. 241 to 245.

Average Precipitation (in inches and hundredths)

Length of Record Years	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
22	4.73	3.20	4.93	3.69	3.93	4.49	4.74	4.58	2.86	2.97	3.09	4.49	47.70

Average Snowfall (inches)

20	6.4	4.9	3.5	0.4	0.0	0.	0.	0.	0.	T.	0.8	4.9	20.9

Average number of days with .01 inch, or more, precipitation.

21	12	9	11	10	10	9	9	9	6	7	8	11	111

Mean Temperature

20	36.4	37.2	47.6	56.2	65.8	73.2	75.8	74.4	69.4	58.6	47.4	36.8	56.6

Mean Maximum Temperature

20	46.2	47.5	58.9	67.9	77.5	84.9	87.4	85.9	81.7	71.6	58.6	46.2	67.9

Mean Minimum Temperature

20	26.7	26.8	36.4	44.4	54.2	61.4	64.3	63.0	57.0	45.6	36.1	27.4	45.3

Highest Temperature

20	76	76	88	89	96	101	104	102	98	96	79	73	104

Lowest Temperature

20	--14	--12	4	20	30	37	46	44	31	20	6	--21	--21

Prevailing Wind Direction

23	sw	sw	sw	sw	sw	sw	sw	sw	sw	sw	sw	sw	sw

Frost Data

Number of Years of Record	Average date of last killing frost in spring	Average date of first killing frost in autumn	Average length of growing season—last killing frost to first killing frost (days)	Latest date of killing frost in spring	Earliest date of killing frost in autumn
23	Apr. 18	Oct. 16	181	May 9	Sept. 14

Average hourly wind movements (miles) at Lexington

Length of Record Years	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
34	13.3	13.6	14.2	13.7	10.5	9.1	8.7	8.3	9.0	10.4	12.2	12.7	11.3

Mean relative humidity, percentage at Lexington, 7 a. m.

34	84	82	79	74	75	78	78	81	80	78	79	83	79

Sunshine, percentage of possible, at Lexington

24	35	40	45	54	62	64	66	65	65	60	49	34	53

TOPOGRAPHY.

Drainage. The principal drainage divide is formed by an east-west ridge along which extends the Madison-Rockcastle County line. Boone's Gap is a part of this ridge which has been lowered by streams cutting headward on both sides of the divide.

From the divide the land, in general, slopes northward to the Kentucky River and southward to the Rockcastle River. North of the divide Silver Creek is the chief stream draining the major portion of the Berea Region. In the eastern section a minor divide runs northward from the main divide, passing across Narrow Gap and continuing to Joe Lick Knob, where it turns to the northeast. The drainage to the west of this minor divide goes ultimately into Silver Creek; to the east the creeks empty into Red Lick and Drowning Creek. Red Lick flows northeast into Station Camp Creek which empties into the Kentucky River. Drowning Creek flows more directly northward into the Kentucky River. South of the divide Roundstone Creek forms one of the principal tributaries to the Rockcastle River. The Rockcastle River empties into the Cumberland River. Both the Kentucky and Cumberland Rivers flow into the Ohio River, so that the water on both sides of the divide finally reaches the same stream.

The small creeks rising in the higher areas of the Berea Region descend swiftly to the more gently sloping stream channels of the lower lands. In time of heavy rainfall or melting snow even these larger lower streams overflow their banks and inundate the adjacent lowlands.

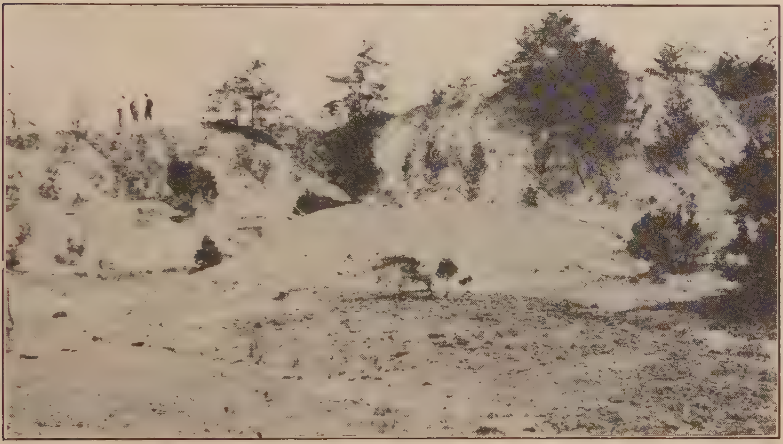

Plate III. THE "CRATER."

Erosion of this knob of soft New Providence shale has formed a crater-like depression. No vulcanism ever occurred in this region. Scene at Blue Lick, Madison County, looking north.

Relief. The Berea Region lies mainly within the Knob Belt, so called because of the knob-like shape of many of the hills which were formed by stream erosion. The shape of the individual knobs is determined largely by the rock composing their upper portion. Knobs topped with soft shale are conical in form. Thus a knob at Blue Lick is known as the "crater," because of its appearance. It is composed of the soft shale of the New Providence. No vulcanism ever occurred in the Berea Region. The knob is entirely due to stream erosion and surface wash. The rock, thought by some to be lava, is a reddish-brown, concretionary, ferruginous limestone layer. Knobs capped with limestone, massive sandstone, or conglomerate have flat tops bordered by cliffs 50 to 200 feet high. An example is the Indian Fort Mountain, once the largest stronghold of the prehistoric inhabitants of Kentucky. (Ref. 2.)

That portion of the Knob Belt which is nearer the Bluegrass, consists of low, gently sloping hills and ridges with level or slightly undulating tops. Bottomlands, one-quarter to one-half mile or more wide, border the creeks. This area merges into the outer Bluegrass which forms the northern portion of the Berea Region.

The table-lands in the area next the Bluegrass, stand about 75 feet above the surrounding valleys. Their tops are all that remain of the once extensive Lexington peneplain. The elevation of this peneplain in the Berea Region is about 1,002 to 1,010 feet above sea-level. The peneplain is believed to have been formed by stream erosion, such as at present is wearing the highlands away from the Bluegrass. Since the formation of the peneplain, two distinct periods of uplift and erosion have occurred. This is shown by river terraces above the flood-plains of the present streams. In some places the terraces are not easily seen. Evidence of these two uplifts is also found along the Kentucky River outside of the Berea Region. Due to these earth movements the streams have cut into the Lexington peneplain. Thus the surface of the old plain upon which Berea College is built will, in time, be entirely worn away.

In recent geologic times the level bottomland between the ridge upon which Berea is built and Twin Mountains was a swamp. The vegetation on dying fell beneath the water and became intermingled with sediments. Later, Brushy Creek drained the swamp, and man aided in the final drainage of the fields. At present the muck soil which had formed at the bottom of the swamp, is cultivated successfully by Berea College, quantities of garden truck being raised on this land.

Away from the Bluegrass the level and rolling land changes into hilly and mountainous topography. At first the more isolated, higher knobs, such as Joe Lick Knob, rise solitary above the slightly dissected lowlands, but as the Eastern Kentucky Mountains are approached, the knobs cluster closer together and the valleys become narrow and V-shaped. Indeed, the southeastern portion of the Knob Belt is one of the most rugged regions in this physiographic division of Kentucky. The highest point is Bear Mountain which is around 1,625 feet above sea level. In contrast, the bench-mark at the Louisville & Nashville Railroad depot, Berea, is 943 feet above sea level. Near the southeastern outer boundary of the Berea Region the Knob Belt merges into the Cumberland Plateau whose mature topography forms the Eastern Kentucky Mountains; and southward it merges into the Mississippian Plateau.

Plate IV. RUGGED KNOB TOPOGRAPHY.

Looking north from Bear Mountain, Madison County, high knobs rise above their narrow V-shaped valleys. The second knob on the right is West Pinnacle. In the distance can be seen the level to gently rolling surface of the Lexington peneplain.

The quite uniformly even skyline of the Cumberland Plateau, as seen in any given region, and of the higher knobs adjacent to the Plateau, has suggested to some geologists that a peneplain existed during Cretaceous times at the elevation of the tops of the higher knobs and mountains. Other geologists believe this even skyline to be the result of rather equal resistance to erosion, and of the structure of the underlying strata. (Ref. 5: I; 17: 195.)

Throughout the hilly and mountainous areas the topography determines the location of the roads. In the roughest surfaced sections the roads or trails parallel the creek's edge and in places wind along the stream bed. They also extend, when possible, along the crest of the narrow ridges, as for example, the road from the Big Hill district westward to the Dixie Highway, and the trail from Bear Mountain southward to the ridge road just described.

Settlements have been made at the intersection of the more frequented roads, villages have developed, and the town of Berea has grown to its present size due to the influence of the geographic controls.

GEOLOGY.

The geologic and geographic history of the Berea Region is told by the sedimentary rocks which make up its entire area. These formations consist of limestones, shales, sandstones and conglomerates. Their total thickness in the Berea Region is approximately 1,048 feet. The limestones were derived originally from the shells of the sea animals who lived in the clear waters of the sea. Coral and other fossils can be seen at the present day in the limestone strata. The temperature, depth of the water and other conditions must have been about the same as they are now in the parts of the world where similar animal life exists. Impure limestones indicate that sand and mud were dropped amid the shell animals. Shales were formed when mud settled to the bottom in great quantities. Sandstones and conglomerates were laid down when the shore lines were nearer to the Berea area, the currents were stronger than during the times in which the mud was deposited or both conditions occurred and sand and pebbles settled to the bottom and were washed up along the shore. Conglomerate was also formed in river channels.

The strata of the Berea Region range in age from the Ordovician to the Pennsylvanian, inclusive. They were all doubtless laid down over the entire area of the Berea Region, as well as in other portions of Kentucky. As time went on the various strata were successively covered by later deposits. Folding of the rock formations tilted them so that erosion has exposed each stratum in ascending geologic order as one goes from the Bluegrass south and southeast in the area described.

The history of the Berea Region is as follows:

During the latter part of the Ordovician Period seas covered the area, and thin-bedded limestones, sandstones and shales belonging to the Richmond stage of the Cincinnatian Series, were laid down. At present they form the northern margin of the surface rocks in the territory described and can be seen, for example, at Kingston.

Beginning at the close of Oswegan times of the Silurian Period (Ref. 17:54), movements of the rock formations of the earth caused the strata to rise out of the sea in a low anticline, or rock fold. Additional crustal movements followed, resulting in a long fold now called the Cincinnati Arch or Anticline. The axis of this Arch extends from the State of Ohio across the Ohio River into Kentucky at Point Pleasant, about twenty miles upstream from Cincinnati. The axis continues southward, passes near Lexington, and bows upward to its highest elevation in Jessamine County, forming what is called the Jessamine Dome. From there it pitches southwest and passes through the eastern part of Monroe County into Tennessee. Near the Kentucky-Tennessee boundary the arch bows up again into the Rutherford Dome of Tennessee.

Plate V. INDIAN FORT MOUNTAIN.

In the distance to the left center of the illustration, Indian Fort Mountain extends from the notch southward toward the right. All of this mountain is not shown. Note the level crest of this knob which is capped by Pottsville conglomerate and sandstone. It is an "outlier," isolated from the Cumberland Plateau. The knob in the distant central foreground is West Pinnacle. Scene looking east from Berea.

During the time the rocks were thus elevated above the surrounding waters, the agents of erosion were so active that by the time the island was submerged in the Middle Devonian Age, the arch had been widely truncated. The evidence of the above events can be seen in the "dropping out in descending order of the strata of the middle and lower portions of the Silurian formations as the axis of the arch is approached." Also the late Silurian and Lower Devonian strata are not found in Kentucky. (Ref. 17:54).

In the Berea area the Niagaran of the Silurian is overlaid directly by the Onondaga limestone of the Middle Devonian. Thus a great unconformity exists between the Silurian and Devonian.

Elevation, erosion and submergence again occurred, and in Upper Devonian times the sea covered the Berea area, and the Ohio black shale, Plate VIII, was deposited unconformably upon the underlying strata. To the west of Berea throughout a strip of about forty miles where the Knobs cross the axis of the Cincinnati Arch in Lincoln, Boyle and Marion Counties, the Middle Devonian and Silurian strata are often missing and the Ohio shale of the Upper Devonian rests unconformably upon the Ordovician. Patches of Onondaga limestone occur; but this unconformity to the west of the Berea Region should be borne in mind in prospecting for oil. In the Berea territory the Onondaga, varying in thickness, lies beneath the Ohio black shale. Land conditions occurred at the end of the Devonian causing an unconformity between the late Devonian and the overlying Mississippian strata.

After the seas flowed over the Berea Region at the beginning of Mississippian times, they covered this territory for long ages. Occasionally during this period the strata would emerge from the sea, erosion take place, and the sea once again sweep over the land surface upon which the strata would be laid down unconformably. Deposition extended westward and probably covered the Bluegrass.

The first formations to be deposited upon the Ohio shale in the Berea territory were the soft New Providence shales of the Waverly Series. A minor unconformity is seen within the Waverly as one ascends the trail from Dixie Highway up Bear

Mountain. Upon very slightly eroded greenish-gray New Providence shale, a gray sandstone was deposited. A disconformity occurs between the impure yellowish Warsaw limestone and the overlying St. Louis limestone. An unconformity is found between the St. Louis and Ste. Genevieve limestones. Many unconformities occur in the Chester.

At the close of the Mississippian the sea withdrew from a large part of the eastern interior. The sediments were exposed as dry land and erosion commenced. In Kentucky the strata near the crest of the Cincinnati Arch were worn away first. This beveling of the Mississippian strata caused the various formations to outcrop in belts. Deep channels were worn in the surficial Mississippian strata. Near Berea the higher Chester shales and limestones were, in places, worn away and the Gasper limestone cut into, as can be clearly seen at East and West Pinnacles, Indian Fort and Bear Mountain.

The Pennsylvanian Period commenced with waters slowly moving westward into Kentucky from a region to the east. It is believed by some (Ref. 9), that this advancing flood of water and sediment formed an enormous alluvial fan. Mississippian and older formations were inundated and upon their eroded surface were laid down the basal rocks of the Pottsville formation, Pennsylvanian System. A great unconformity was thus formed between the Mississippian and Pennsylvanian Systems. The Pottsville varies in thickness due to irregularity of the surface of the underlying Mississippian formations, unequal rate and length of deposition, and position relative to the shoreline or river bank.

A channel worn in the Mississippian and filled with Pottsville pebbles and sand is found to the southeast of Berea. Here Rockcastle conglomerate of the Pottsville fills a valley eroded into the limestone of what is at present the Pinnacles, Dome and Indian Fort Mountain. Water-worn quartz pebbles and sand, cross-bedding, and ripple-marks are easily found. A similar Pottsville-filled channel in the Mississippian also occurs on the south side of Bear Mountain. The Chester shales and limestones, but no Rockcastle conglomerate occur on the north side of this knob. On the south side a bold ledge of cross-bedded

Rockcastle conglomerate occurs. Hence the north and northwest sides of what is now Bear Mountain formed the river bank of this ancient channel worn in the Mississippian and filled by pebbles and sand from the advancing Pennsylvanian waters. A continuation of this channel-filling occurs on the knob adjacent to Bear Mountain on the south. Only a low saddle caused by recent stream erosion separates the knobs. Shore conditions also existed at various times throughout the Pottsville Age.

In certain areas to the east of the Berea area, the conglomerate is lacking and a sandstone takes its place. To the west of Berea the Pottsville waters spread over the Cincinnati Arch, sand and gravel being deposited in the Mississippian valleys. The strata thus laid down connected what are now the Eastern and Western Coal Fields of Kentucky which have since been separated by erosion. The Appalachian and Eastern Interior Coal Fields of which the two coal fields of Kentucky respectively form parts, were thus once connected, as proved by the author's investigations.[1]

As Pennsylvanian times continued, extensive swamps came into existence and coal in commercial quantities was formed. One or more swamps occurred in the Berea Region as evidenced by the coal on Bear Mountain, Big Hill and other districts to the east and south. The greater part of the coal in the Knobs has since been lost by erosion. After these swampy times, deeper water again covered the region and sandstone and shale were formed.

At the close of the Pennsylvanian, Kentucky was elevated and the Berea Region together with the greater part of the State has never again been completely covered by the sea. The area has been subjected to erosion by streams and wind, erosion being greatest near the axis of the Cincinnati Arch. Here the younger formations have been worn away and the Ordovician strata cut into forming the Bluegrass. Erosion is wearing away the strata in a circle outward away from the axis of the Cincinnati Arch. During Cretaceous times a peneplain may have been developed at the elevation of the tops of the higher knobs and "mountains" forming the Cumberland Plateau. By Tertiary times, M. R. Campbell (Ref. 5:1), believes a base-level condition had been attained over that part of the Bluegrass and adjacent Knob Belt which is called the Lexington peneplain. Uplift of the strata in Kentucky during recent geologic times caused the streams to deepen their valleys in the peneplain and commence to erode it.

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[1] Burroughs, W. G. Pottsville-filled Channel in the Mississippian; Kentucky Geol. Survey, Series VI, Vol. X, pp. 115-127, map, 2 sections, 1923.

All the time the mountains and plateaus are being worn away and the Knob Belt follows the retreating highlands. On the side toward the Bluegrass the Knob Belt itself is being obliterated. These processes are going on at the present moment.

Due to this erosion the outcrops of the strata of the Berea Region are as follows: Ordovician strata form the surface rocks on the northern margin or Bluegrass portion of the area. The rolling land adjacent to the Bluegrass is composed of Silurian limestone and shale. Next outward is found the outcrop of the Onondaga limestone of the Middle Devonian. An exposure of Onondaga occurs near the intersection of the Dixie Highway and the road running east and west past the fair grounds to the north of Berea. Then comes the outcrop of the Ohio shale of the Upper Devonian, the surface rock of which forms the lower knobs, valleys and dips beneath the base of the higher knobs. Berea is built on Ohio shale, while here and there a patch of Waverly shale of the Mississippian. Many of the larger knobs are made up of Mississippian shales, sandstones and limestones. Twin Moun-

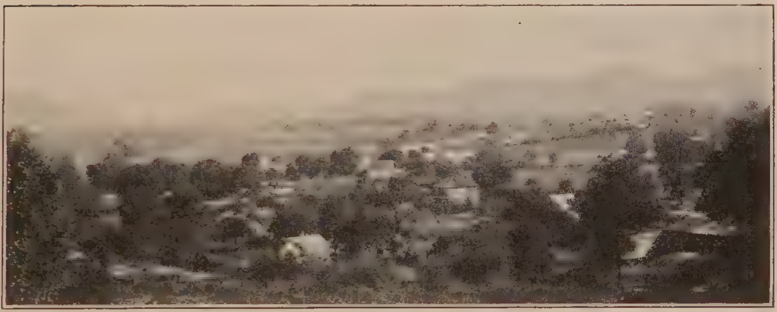

Plate VI. KNOBS OF THE BEREA REGION.
Scene looking southeast from Berea.

tain is topped by a shaly sandstone of the Waverly. The gray cliff-forming limestone seen in the knobs to the southeast of Berea is the Mammoth Cave and Gasper limestone of the Mississippian. The Chester shale and limestone is found near the top of Bear Mountain, topped by Pottsville sandstone and shale. On West Pinnacle, the Dome and Indian Fort Mountain, the Rockcastle conglomerate of the Pottsville lies upon the Gasper limestone, due to the overlying Chester having been worn away during Mississippian times. In some places to the south and east of Berea sand was laid down in place of pebbles and the Rockcastle conglomerate is missing.

The future geologic history of the Berea Region is clear. Every particle of rock that is worn from the knobs advances just that much the wearing away of the younger rocks and the uncovering of the strata that lie beneath. Some day in the distant future the surficial rocks of the Berea Region will have been entirely eroded away and in their place will be level or rolling limestone soil. The great length of time that elapsed while the present topography was being formed and the ages that must pass before the Berea Region becomes entirely fertile limestone land, is shown by the fact that the Mississippi River basin at the present day is reduced by erosion only one foot vertically in 3,500 years. In the Berea Region, however, due to the steep gradient of the streams, erosion will take place more rapidly than in the case of the entire Mississippi drainage basin.

STRATIGRAPHY.

The formations occurring in the Berea Region considered in ascending geologic order are here given. The total thickness of each formation is stated in the geologic column. The thickness of the strata, however, varies considerably in different localities.

GEOLOGICAL FORMATIONS OF THE BEREA REGION.

With Their Thicknesses, and Characteristic Fossils.*

Group	System	Series	Stage	Sub-Stage	Character of Strata	Characteristic Fossils	Thickness in feet
Paleozoic	Pennsylvanian	Pottsville	Lee		Sandstone, shale Coal, Shale	Land plant remains.	0-72 0-30 inches 0-16
				Rockcastle	Conglomerate		0-65
	UNCONFORMITY						
	Mississippian	Chester	Pennington		Largely green and red shales, sandstone, limestone.		0-35
				Glen Dean	Fossiliferous limestone, thin layers of shale.	Prismonora serulata, Archimedes laxus Pentremites godoni	0-40±
				Golconda	Mainly green shale.	Pterotocrinus capitalis, Pentremites obesus.	0-3+
				Gasper	Limestone (oolitic)	Talarocrinus patei, Pentremites godoni, P. pyriformis	40±

*Fossils after Miller, A. M., Geology of Kentucky: Dept. of Geology and Forestry of Ky., Ser. V. Bulletin II, 1919. For additional lists of fossils see Mississippian Series of Eastern Kentucky, by Chas. Butts: Ky. Geol. Survey, Series VI, Vol. 7, 1922.

GEOLOGICAL FORMATIONS OF THE BEREA REGION—Continued

Group	System	Series	Stage	Sub Stage	Character of Strata.	Characteristic Fossils.	Thickness in feet
Paleozoic	Mississippian	Mammoth Cave	Ste. Genevieve		Limestone (oolitic and non oolitic)	Platycrinus huntsvillae, Lithostrotion hermodites	45
			SLIGHT UNCONFORMITY				
			St. Louis		Gray limestone, contains chert (non-oolitic).	Lithostrotion canadense and proliferum.	30
					Argillaceous limestone weathers to clay.		13 18
		UNCONFORMITY					
		Waverly	Warsaw		Limestone (siliceous, impure yellowish)	Spirifer lateralis, Productus magnus.	25±
					Sandstone and shale layers.		9
				Wildie	Sandstone (Rockcastle freestone)		10½ in.
					Green glauconite shale		1±

GEOLOGICAL FORMATIONS OF THE BEREA REGION—Continued

Group	System	Series	Stage	Sub-Stage	Character of Strata.	Characteristic Fossils.	Thickness in feet
Paleozoic	Mississippian	Waverly	Logan*		Sandstone and shale		210
			Cuyahoga*		Mainly soft greenish gray shale, Ironstone concretions.	Cyathaxonia cynodon. Taonurus caudagalli. Fragments of large crinoid stems.	172
					UNCONFORMITY		
	Devonian	Upper Devonian	Genesee	Ohio	Black bituminous shale. (Oil shale).	Lingula spatulata, Dinichthys, Silicfied. wood. (Dadoxylon, a Cordiates genus).	80-117
					UNCONFORMITY		
		Middle Devonian	Onondaga		Magnesian, cherty limestone. Often porous and containing oil and gas.	Spirifer acuminatus, Spirifer gregarius, Stropheodonta hemispherica and most of corals of reef at Falls of Ohio at Louisville.	3 in. to 13½ ft.

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*Logan and Cuyahoga comprise New Providence formations according to Charles Butts, Mississippian Series of Eastern Kentucky, Ky. Geol. Survey, Ser. VI, Vol. 7, p. 37.

GEOLOGICAL FORMATIONS OF THE BEREA REGION—Continued.

Group	System	Series	Stage	Sub-Stage	Character of Strata.	Characteristic Fossils.	Thickness in feet
	UNCONFORMITY						
Paleozoic	Silurian	Niagaran	Alger	Estill	Plastic blue gray shale	Chonetes venustus	0-2
				Waco	Magnesian limestone and gray shale	Favosites gothlandica	0-4
				Lulbegrud	Gray shale.		10-13
			Indian Fields	Oldham	Thin bedded magnesian limestone and shale.	Strictlandia norwoodi	8-12
				Plum Creek	Gray shale and thin limestone		4-5
				Brassfield (Ky. Clinton)	Magnesian limestone (bluish on fresh surface, weathers a rusty brown).	Fluted crinoid stem plates. Cyathophyllum calyculum Whitfieldella subquadrata.	17
	UNCONFORMITY						
	Ordovician.	Cincinnatian.	Richmond	Saluda	Sandstone and argillaceous limestone	Columnaria, Calapoecia, Tetradium.	20 +
				Liberty	Thin bedded limestone and shale	Beatricea. Streptelasma rusticum. Herbertella insculpta.	50 +

ORDOVICIAN SYSTEM.

Liberty Formation. Strata of the Liberty sub-stage of the Richmond stage of the Ordovician are the lowest formations in the geological column of the Berea Region. The Liberty is composed of shale and thin-bedded greenish-blue or bluish limestone. Its total thickness is 50 feet.

Saluda Formation. The Saluda is the top formation of the Richmond. It is made up of argillaceous limestone and fine-grained, thin-bedded sandstone. The total thickness is about 20 feet. The Richmond formations outcrop in the northern portion of the Berea area.

SILURIAN SYSTEM.

The Niagaran series, which are the only Silurian strata present, are as follows:

Brassfield Stage. The lower part of the Brassfield, Kentucky Clinton, formation as defined by A. Foerste (Ref. 7:27), is made up of one or more massive beds of magnesian limestone which is somewhat bluish when freshly broken but weathers to a rusty brown. The middle and upper parts are composed of thinner-bedded limestone layers. Near the top of the formation the limestones are often interbedded with thin beds of clay. They weather to a rusty, yellowish brown. The total thickness of the massive strata and of the formation as a whole varies considerably. The massive layers are eight feet thick southeast of Bobtown, and only two feet thick about four miles north of Berea and a half mile south of Whites Station.

The total thickness of the Brassfield limestone formation as measured at the northern end of Jackson Hollow about four and one-half miles northeast of Berea and about one mile southeast of Bobtown, is 17 feet. (Ref. 7:29).

Plum Creek Shale or Clay. This formation consists of bluish-gray shale with several layers of thin limestone. About four miles north of Berea toward Whites Station, it has a total thickness of about five feet.

Oldham Formation. Thin magnesian limestone interbedded with much shale makes up the formation which varies in thickness from eight to twelve feet. In the Louisville & Nashville Railroad cut south of Whites Station, the Oldham formation consists of limestone interbedded with clay, the total thickness being eight feet, three inches. (Ref. 7 :49). At this outcrop fossils are found near the top of the formation.

Lulbegrud Shale or Clay. It is bluish-gray in color and weathers to a soft plastic clay. In the Berea Region it varies from ten to thirteen feet in thickness. Ground water seeping from the Lulbegrud shale often contains Epsom salts.

Waco Formation. Overlying the Lulbegrud shale near the village of Waco and to the eastward is a solid massive gray limestone layer nine to twenty-four inches thick, which occurs over wide areas. Above this limestone come numerous layers of thin-bedded, fossiliferous limestones interbedded with soft shale. The total thickness of the clay is greater than that of the limestone. Concerning the massive basal limestone of this formation, A. Foerste states, "An attempt has been made to identify with this solid limestone at the base of the Waco section, the various exposures of limestone having about the same thickness occurring in the Alger clay section between Brassfield and Berea, but the interval between the top of the Oldham limestone and the heavy layer of limestone thus identified differs so much at various localities that only detailed stratigraphical work can establish their identity, in the absence of the fossiliferous part of the Waco section. West of Berea, at Hammack, and at Crab Orchard the solid layer of limestone occurs only six or seven feet above the base of the more continuous clay section." Thus in the Berea area the Waco formation, unless represented by the massive limestone layer discussed above, consists of only a few feet of shale overlain by Onondaga limestone and in some localities was worn away before the deposition of Devonian strata.

Estill Shale. This shale is soft, plastic and of a bluish-gray color resembling the Lulbegrud shale. It thins out as the axis of the Cincinnati Arch is approached. In places near Berea it has been eroded away before the deposition of the overlying strata or has become merged with the Waco horizon.

DEVONIAN SYSTEM.

Onondaga Limestone. The Lower Devonian is absent in Kentucky and the Middle Devonian limestone, known as the Onondaga, in the Berea Region rests upon Niagaran strata. The Onondaga is a massive, cherty, gray, magnesian limestone. (Plate VII). A few inches to several feet of the top portion of the Onondaga usually consists of a massive limestone layer which weathers to a brownish color. In certain localities it has a brecciated appearance, in others this feature is not present. It sometimes contains fossils such as coral and crynoid stems. This layer is called by A. Foerste, the Duffin layer (Ref. 7:99, 101).

Plate VII. ONONDAGA LIMESTONE.

Outcrop near intersection of east-west road past Berea Fair Grounds and the Dixie Highway. Bed shown in illustration 8 to 12 inches thick. Lighter colored areas are chert.

The Onondaga varies considerably in thickness. A few hundred yards north of the Louisville & Nashville depot at Berea, the Ononodaga outcrops in the ravine both east and west of the railroad track. Here it is about 13½ feet thick. But four miles north of Berea near Whites Station (Ref. 7:90, 93), it is only three inches in thickness, being made up of blue, argillaceous, gritty limestone which contains fish remains. In the same few inches at the base of the limestone fish remains are found in other localities. Near the Berea Fair Grounds the Onondaga is about six feet thick. Northeast of Berea near Bobtown the Onondaga limestone is one foot and less in thickness.

One and one-quarter miles southeast of Bobtown it is about four feet four inches thick. The Devonian limestone thus appears to thin irregularly toward the north of the Berea area.

Ohio Shale. The Upper Devonian is represented by the Ohio shale formation which rests unconformably upon the Onondaga limestone. The Ohio shale is a black, carbonaceous, fissile shale. At Berea, two or three layers of green shale occur fifteen to twenty feet below the top of the Ohio shale. They were exposed in the excavations made for the large chimney of the Berea College power-plant, and can be seen to less advantage in the eastern part of the town. At the base of the Ohio shale is

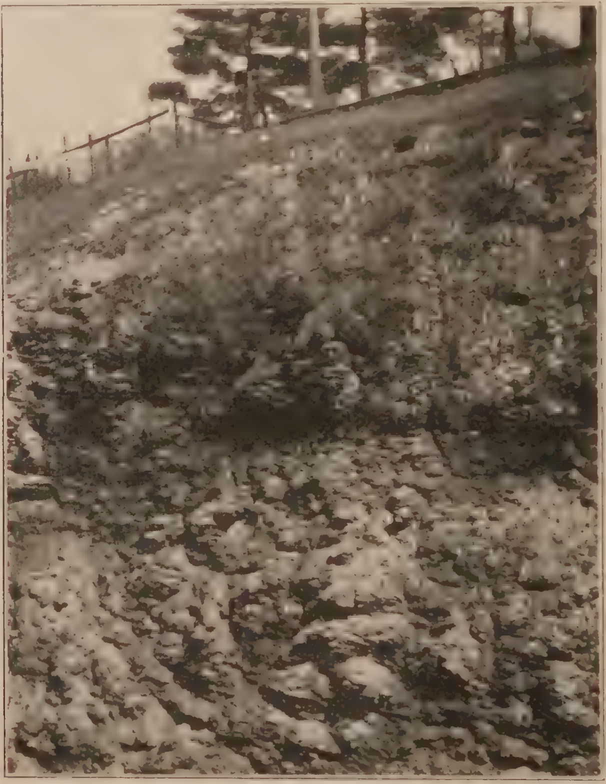

Plate VIII. OHIO SHALE.
East side of Louisville & Nashville Railroad cut at Berea. Thickness of black shale here shown is 70 feet.

a brown, calcareous sandstone layer, about one foot thick. The total thickness of the Ohio shale in the Berea Region is from 80 to 117 feet. Bituminous matter occurs in such quantities in the Ohio shale that oil and gas have been distilled from it.

The Ohio shale, the upper few feet of which may be the black Sunbury shale, forms the surface rock for large areas of the more gently rolling Knob country and is the base upon which many of the higher knobs rest. Berea is built upon a ridge made up of Ohio shale.

Mississippian System.

Waverly Series

The Waverly Series of the Mississippian System rests unconformably upon the Ohio shale of the Devonian. Waverly strata make up many of the smaller knobs, as well as the slopes of the higher knobs from the Ohio shale at their base to the bottom of the Mammoth Cave limestone.

New Providence Formations. The lowest formation of the Mississippian in the Berea Region is the New Providence. Here it has a total thickness of about 382 feet. The New Providence is separated into two divisions called the Cuyahoga and Logan. The Cuyahoga forms the lower portion. It consists of soft, grayish-green shale in which harder, calcareous shale layers occasionally occur. Reddish-brown concretions composed of carbonate of lime and iron, are numerous. On exposure to the weather the concretions break up into thin, curving, shell-like, reddish-brown fragments. A concretionary layer of lime and iron carbonate about eight inches thick is found in the Cuyahoga. Phosphatic nodules are sometimes found near the base of the Waverly. The Logan division commences near the middle of the New Providence where 20 feet of thin-bedded sandstone rests upon soft Cuyahoga shale. The Logan, as a whole, consists predominantly of thin, shelly, gray sandstone with some gray shale. The sandstone on weathering breaks into rather small, sharp-edged pieces. A reddish clay shale, eight feet thick occurs in this formation on Indian Fort Mountain.

Warsaw Formation. Above the New Providence strata come the Warsaw sandstone, shale and limestone of the Waverly Series. The Warsaw contains siliceous geodes. Many of these have rolled down the slopes of the knobs and are found at lower elevations than the Warsaw.

The Wildie sandstone is an important member of the Warsaw in Rockcastle County where it is quarried for building stone near Wildie. It is a uniformly very fine-grained, gray sandstone of medium hardness. At the Pinnacles it is 10½ inches thick. It thickens toward the area of quarry operations in Rockcastle County.

Just below the Wildie comes a green, glauconite shale about one foot thick. At Owsley Fork near the caves, the glauconite is concentrated and forms the dark green rock, fragments of which are seen in the creek bed. Glauconite is an iron and potash silicate.

Above the Wildie comes several feet of shale and two thin sandstone beds overlain by about 25 feet of impure, yellowish, coarse limestone. The limestone beds are about one foot thick. The total thickness varies as the formation was subjected to erosion before deposition of the overlying strata.

Mammoth Cave Series. These limestones, with the overlying Gasper limestone of the Chester, form the gray cliffs that are seen near the tops of the higher knobs. The Mammoth Cave limestone is the same formation in which Mammoth Cave occurs. It is made up of two formations, the St. Louis and the Ste. Genevieve.

The St. Louis limestone comprises the bottom portion of the Mammoth Cave Series. It rests unconformably upon the eroded surface of the yellowish, impure, siliceous limestone of the Warsaw. The St. Louis is chiefly a moderately thick-bedded, fine-grained, non-oolitic, dark gray limestone. Blue and light gray beds also occur. The basal beds of the St. Louis, 13 to 18 feet in total thickness, are argillaceous, thick-bedded limestone. They weather to clay. Yellowish chert is found quite abundantly in the St. Louis. Fossil coral are of frequent occurrence. The St. Louis, as a whole, varies in thickness. Near Berea it is about 48 feet thick.

The Ste. Genevieve limestone rests unconformably upon the St. Louis. A fine conglomeritic layer a few inches thick is found in the basal portion of the Ste. Genevieve. Tiny quartz pebbles also occur scattered through the limestone. The Ste. Genevieve in the Berea Region is usually very thin-bedded, the beds being one-eighth to one-half inch thick. A few thicker beds occur. The limestone is light gray and generally oolitic, although a few non-oolitic beds are found. The oolitic character of the Ste. Genevieve readily distinguishes it from the non-oolitic St. Louis limestone. The upper member of the Ste. Genevieve is known as the Ohara. The Ste. Genevieve, which varies in thickness, is about 45 feet thick in the vicinity of Berea.

Chester Series. These formations overlie the Ste. Genevieve limestone formation. In the Berea Region the Chester is represented by the Gasper, Golconda, Glen Dean and Pennington formations. All of these formations have been identified by Chas. Butts five miles southeast of Berea. At the Pinnacles and many other localities the last three formations were eroded away before deposition of the Pennsylvanian strata, in consequence of which the Rockcastle conglomerate of the Pottsville rests on the Gasper oolite. Pilot Knob is capped by Gasper oolite.

The characteristics of these Chester formations are as follows: The Gasper is chiefly an oolitic limestone which has in general the same appearance as the underlying Ste. Genevieve oolite. A little shale also occurs in some regions. Gasper oolite is light gray to bluish gray in color. Due to erosion at the close of the Mississippian the Gasper varies locally in thickness. At one point on Indian Fort Mountain where overlain by Rockcastle conglomerate it is 40 feet thick.

The Golconda formation in eastern Kentucky is chiefly a soft green shale which overlies the Gasper. In some regions limestone also occurs in the Golconda.

The Glen Dean formation is almost entirely a medium to thick-bedded, coarse-grained, fossiliferous, bluish limestone with some thin layers of shale.

The Pennington formation consists mainly of soft red and green shale with a smaller amount of argillaceous red, blue or gray, fossiliferous limestone and some fine-grained, shaly sandstone. The red color of the strata is characteristic of this formation. The Pennington at Morrill (Ref. 3:180), southeast of Berea is about 35 feet thick.

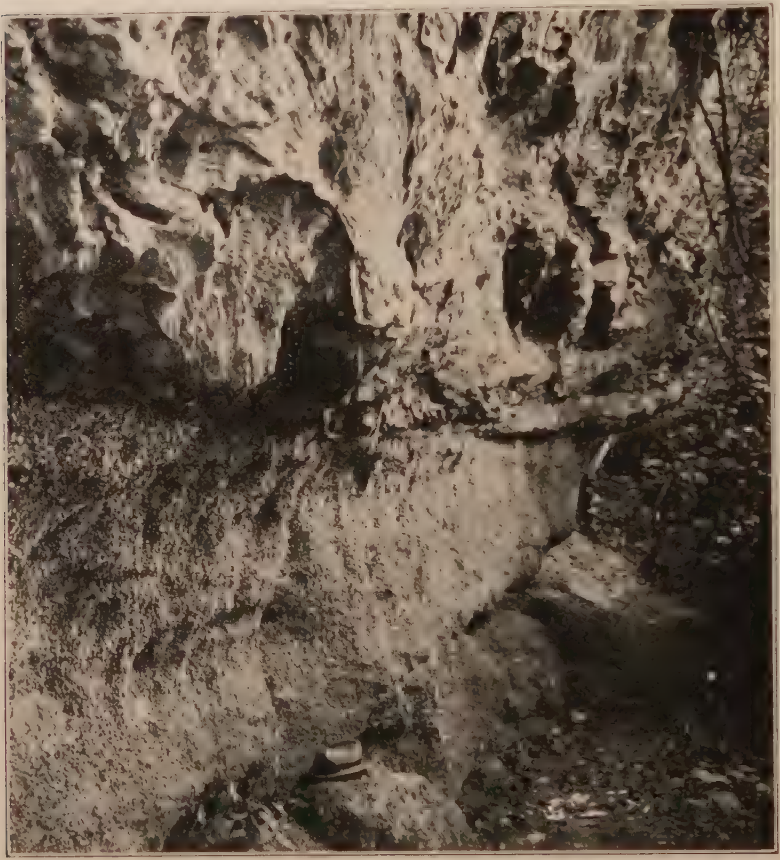

Plate IX. CLIFF OF POTTSVILLE CONGLOMERATE, SHOWING BED OF QUARTZ PEBBLES.

This exposure is on the northward side of Indian Fort Mountain, Madison County. Note the bed of quartz pebbles extending from the bottom of the cliff to near the center of the illustration. The sandstone above has been eroded into fantastic forms. Size of objects can be ascertained by comparison with the hat in lower center.

The Golconda, Glen Dean and Pennington are often absent due to erosion prior to deposition of the Pottsville strata.

PENNSYLVANIAN SYSTEM

Pottsville Series. In the Berea Region this series consists of the basal Rockcastle conglomerate and sandstone overlain by shale and sandstone. The conglomerate (Plates IX-XII) is made up of water-worn quartz pebbles cemented together with coarse sand. Iron oxide enters into the cement to quite an extent, giving a reddish brown color to certain outcrops. Some of the pebbles in the conglomerate on Indian Fort Mountain are as large as English walnuts but usually they are much smaller. Cross-bedding of the conglomerate and sandstone (Plate XVII), is found in many places, as for example, just below the abandoned quarry at the Indian Fort. Ripple marks occur in the Pottsville sandstone. The conglomerate found on the Pinnacles and Bear Mountain was laid down in river channels which had been eroded in the surface of the Mississippian formations before the beginning of the Pennsylvanian Period. The thickness of the conglomerate proper as found today thus varies from zero where once was the land on either side of the river channel, to 65 or more feet in the deepest parts of the channel. The total thickness of the Pottsville including both conglomerate and overlying sandstone and shale ranges up to about 155 feet.

In some localities of the Berea Region coarse sandstone occupies the horizon of the conglomerate at the base of the Pottsville Series.

A bituminous coal seam 24 to 30 inches thick occurs sixteen feet above the top of the conglomerate in the lower portion of the Pottsville. It is found near the top of Bear Mountain and in the Big Hill district. The majority of the knobs in the Berea area are too low to catch this coal seam.

STRUCTURE.

The Berea Region lies on the southeastern flank of the Cincinnati Arch. The strata dip in a general southeasterly direction at a small angle. The dip and strike at a given point vary according to the local folds in the rock. Strata that outcrop to the north of Berea dip beneath the overlying formations to the south and southeast of the town. These surficial strata in turn dip under Mississippian and Pennsylvanian formations.

The geologic column in this report shows the character, thickness and geologic order of the formations in the Berea Region. By noting the formation at the surface, one can ascertain by consulting the geologic column what formations underlie the surficial rock.

Several anticlines and synclines occur in the Berea area. A structural contour map can be obtained from the Kentucky Geological Survey, Frankfort, Kentucky. (Ref. 13). Oil and gas have accumulated in at least some of the anticlines. This subject is discussed further under the topic of Oil.

Plate X. JOE LICK FAULT.

Waverly shale occurs to the left of the road until dark strata is seen in the upper right-hand corner of the illustration. This dark strata is Ohio shale. The fault plane is at the contact of these two formations. The Waverly has been faulted downward. Scene along the road which extends north and south just west of Joe Lick Knob, Madison County. The fault here shown stretches in a general northeast-southwest direction, passing south of Joe Lick Knob. View looking south.

Faulting has occurred in several places in and near the Berea area. The two parallel major faults of the Irvine oil field as traced by the author, extend in a general southwesterly direction from Estill County across Madison County passing just north of Berea and Wallaceton. Continuing southwesterly through Garrard County they pass on to the westward. The distance between the two faults varies but is usually one-half to three-quarters of a mile. The strata throughout this block has been downthrown. In some places the throw is 150 feet. Combs Mountain and Joe Lick Knob occur within the down-faulted block, a fault passing to the north and another to the south of these high knobs. West of the Louisville and Nashville Railroad the fault changes into a great anticlinal fold with no definite displacement discernible. But the fold again soon becomes faulted. A large anticline usually occurs adjacent to the south of the south fault.

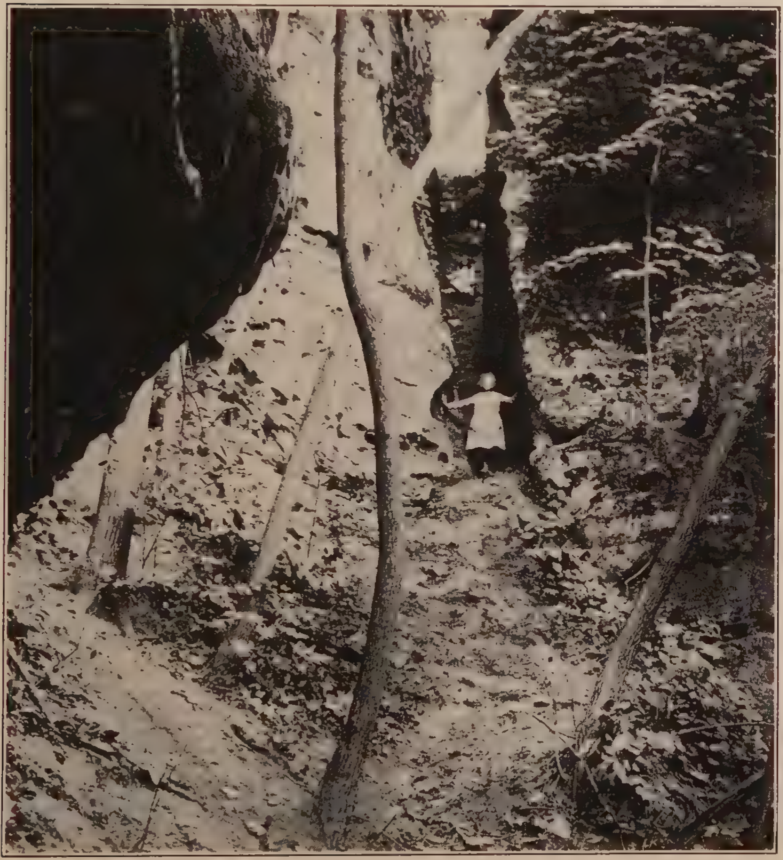

Plate XI. THE DEVIL'S SLIDE.

The enlarged joint-plane in Pottsville conglomerate here shown occurs near the west end of Indian Fort Mountain, Madison County. Scene looking up the joint-plane toward the south.

The faults are readily seen on the road passing just west of Joe Lick Knob. The south fault occurs about one-half mile southwest of Joe Lick Knob. The fault is clearly seen on the north side of the crest of the hill of Ohio shale. Here the Waverly has been brought down on the north side of the fault plane and the Ohio shale has been thrust up on the south. Due to erosion the softer Waverly shale now forms the lower portion of the ridge and lies in the valley beyond to the north, while the harder Ohio shale forms the crest and main portion of the hill to the south. The north fault crosses this road at the north end of Joe Lick Knob. Another gravity fault occurs between Berea and Kingston north of the parallel faults described above.

Joint planes can be seen well developed in the bed of Brushy Creek at the Dixie Highway bridge just south of Berea and in the creek bed at the bridge on Prospect Street. On Indian Fort Mountain the Devil's Slide, (Plate XI), the entrance to the fort from the Dome, and other large crevices are joint planes which have been enlarged by weathering and slumping of the rock.

SOILS.

The majority of the soils of the Berea Region are residual, being formed by disintegration of the underlying strata. On the steeper slopes and at their base the residual soil may be mixed with material from higher formations, brought down the hillside by surface water and gravity. The floodplains of the creeks contain transported soil deposited by the streams. This alluvium occurs in rather narrow strips of limited extent.

The residual soils, briefly described, are as follows: The deep, loamy soil derived from the lower portions of the Richmond formation, makes good farming land; but the upper Richmond makes a clayey soil that is cold and sticky when wet and that bakes hard during dry weather. This type of soil varies and some areas compare favorably with the deeper loam from the lower Richmond.

The Silurian and Devonian magnesian limestones do not produce a very good soil. The Niagaran shales, and clays derived therefrom, are, however, often highly calcareous. Mr. Robert

Spence, Madison County Farm Agent, who conducted experiments in the use of this marly shale and clay as a substitute for crushed limestone on the fields, found that it considerably increased the yield.

The Ohio shale soil is a silt loam or silty clay. The subsoil is a heavy silty clay, or clay. When the bedrock is near the surface, pieces of black shale are mixed with the soil. Much of the Ohio shale area like the other soils of the region, requires artificial drainage if crops are to do their best. The soil is naturally poor for agricultural purposes.

Muck land surrounded by Ohio shale soil, occurs just south of Berea. The area was formerly a swamp. The soil consists of black, organic and earthy material. Due to stream erosion, supplemented by artificial drainage, the swamp was drained and the land is now farmed by Berea College students.

The soils of the Waverly formation usually occur on the knob slopes. The shale soils wash badly unless held in place by vegetation. There occur limited areas of sandy soil derived from Waverly sandstones. Rock fragments are washed down from the Mammoth Cave limestone and Pottsville conglomerate formations, when these strata are present. The limestone fragments aid in enriching the Waverly soils.

The Mammoth Cave limestone is covered with a residual soil which is a brown silt loam. It is a fair soil for agricultural purposes, but lacks the phosphate content that makes the Bluegrass limestone soils so extremely productive. The limestone often outcrops around the margin of the knobs forming high cliffs.

Soils of the Chester strata are not very important as they occur near the tops of the highest knobs and are of limited extent.

Knobs capped with Pottsville conglomerate may have little or no soil. But in some places a sandy loam has developed from the underlying sandstone strata. Fragments of sandstone are scattered through the soil. When properly cared for, this type of soil makes quite good farm land. An example of this soil is found near the northern end of Indian Fort Mountain. The conglomerate often forms bold cliffs where it outcrops along the sides of the knobs.

MINERAL RESOURCES.

The Berea Region contains several non-metallic mineral deposits which are, or will be, of economic value. A description of these natural resources is here given.

Clays. Several different geological formations occur in this region from which clays and shales of commercial value can be obtained. Their outcrops have already been defined in this report. Considered in ascending geological order, these formations are as follows:

(1) From the Ordovician to the Mississippian, inclusive, there are several limestones which have, in places, weathered to a residual clay suitable for the manufacture of brick.

(2) The Silurian System contains the Lulbegrud and Estill formations. They are made up of smooth, plastic, blue-gray shales which, together with the clays derived from them, are adapted to the manufacture of building brick, hollow blocks, drain tile and earthenware. The detrimental feature is that the Lulbegrud shale is less than 15 feet thick, and the Estill shale, if present, is only two or three feet thick. The Estill shale thickens to the eastward of the Berea Region. The Niagaran shales and clays are sometimes highly calcareous and are of value to spread on the fields for their lime content.

(3) The Devonian System contains the Ohio shale, which is black, carbonaceous, fissile, and on weathering first breaks down into small, thin pieces. In this condition the Ohio shale is non-plastic when ground and mixed with water, and is of no value for the manufacture of clay products. Further weathering produces an arenaceous clay of a reddish color from which brick and drain tile can be made. Berea College, in former days, used weathered Ohio shale clay at its brick yard one mile north of the Louisville & Nashville Railroad depot at Berea. This brick is said to have been used in Ladies' Hall, and other college buildings.

(4) The Mississippian System contains the Cuyahoga shale of the New Providence formation which is extensively used in

the clay products industries in other portions of the Knob Belt. It is a soft, greenish, or greenish-gray shale. The unweathered shale can easily be ground, and when mixed with water is plastic. On weathering it becomes a plastic clay. This shale forms the lower portion of the higher knobs in the vicinity of Berea. It also occurs in certain of the smaller knobs, such as the "crater," at Blue Lick. In places the Cuyahoga shale of the New Providence is 172 feet thick. Some of the knobs toward Boone's Gap contain this shale in quantity, favorably situated as regards transportation over the Louisville & Nashville Railroad. The New Providence shale and clay make good common brick, hollow block, drain tile, paving brick and red earthenware.

The Mississippian System also contains the Pennington shale of the Chester Series. A sample taken from its outcrop near the top of Bear Mountain, was plastic and fired to a light red color. (Ref. 19:144). This deposit, however, can be reached only over a long stretch of poor road with steep slopes. Due to its topographic position, this strata and residual clay are of no economic importance.

(5) The Pennsylvanian shales and clays are found topping some of the higher knobs. For use in the clay products industry they are of little or no value.

(6) Small patches of transported clays occur in some of the larger stream valleys.

(7) East and northeast of the Berea Region are isolated deposits of very light gray clay belonging to the Irvine formation, Tertiary in age. This clay is often of high quality. In places, however, it may contain considerable arenaceous material. The Irvine clay, when pure, is made into stoneware and art pottery, at Waco and Bybee.

The Berea Region contains an abundant supply of clay and shale suitable for various purposes in the clay products industry. But before locating a clay products plant at any point, the following conditions should be carefully investigated. There should be an ample amount of good, uniform quality shale or clay, well adapted for use in the manufacture of the products desired. The special uses to which the shale or clay is best suited can be determined by examining their physical properties. These properties, each of which should be tested separately, include plasticity, water of plasticity, shrinkage, fineness, transverse strength, bonding strength, slaking test, vitrification, color after firing, and fusion. (Ref. 19:15). The refractory character of a shale or clay can also be ascertained by chemical analysis. A low percentage of fluxing impurities indicates a refractory clay.

The shale or clay deposit should have little if any overburden throughout the area to be worked. Mining should be easy and economical. The deposit should be near a railroad. If, however, the plant is to make a product of high value per pound, such as art pottery, it can be situated at a greater distance from the railroad than can a plant manufacturing a heavier, cheaper article. Fuel should be plentiful and cheap. Labor, both skilled and unskilled, should be obtainable at reasonable wages. Relative to marketing of the product, a small brick and drainage tile plant might successfully supply the local demand, if it could put out an excellent product which would sell as cheaply or for even less than the larger companies at a greater distance could offer their products in this region. The distance to which the local plant could extend its market would depend on economic conditions. The higher the value per pound of the article produced, the greater the distance it could be shipped to the consumer.

Sand and Gravel. The Pottsville conglomerate is used for sand and gravel. It is secured from the weathered outcrops near the tops of the highest knobs. Rock which is greatly weathered but still stands in steep cliffs, is blasted down, broken into a mass of sand and gravel, and screened. It is a long haul to the valley below, but the wagons are empty on the uphill trip. Two such quarries, one now abandoned, occur on Indian Fort Mountain.

Gravel can be obtained in patches from the floodplains of some of the streams.

Stone. Certain of the rock formations can be utilized for building stone, road metal, ballast, lime, cement, concrete, agricultural lime and similar purposes. Considered in ascending geological order the formations suitable for each of these purposes are as follows:

The Ordovician, Silurian and Devonian limestones which outcrop to the north of Berea, where covered by only a small amount of overburden, will furnish a plentiful supply of ballast, road metal and rock for similar purposes. These formations outcrop in numerous places along the pike from Berea to Richmond, as well as at many other localities in their respective belts. The Onondaga limestone of the Devonian outcrops in the gully near the Berea Fair Grounds, and also for a short distance along the Dixie Highway nearby. It forms a ledge in a ravine to the east and west of the Louisville & Nashville Railroad a few hundred yards north of the Berea depot. Large quantities of this stone are easily available in the fields to the north of the ravine. The Onondaga again outcrops on both sides of the Louisville & Nashville tracks two miles north from the Berea depot. At both places mentioned the Onondaga is favorably situated for transportation by rail, and on being quarried and crushed could readily be shipped. Northward towards Whites

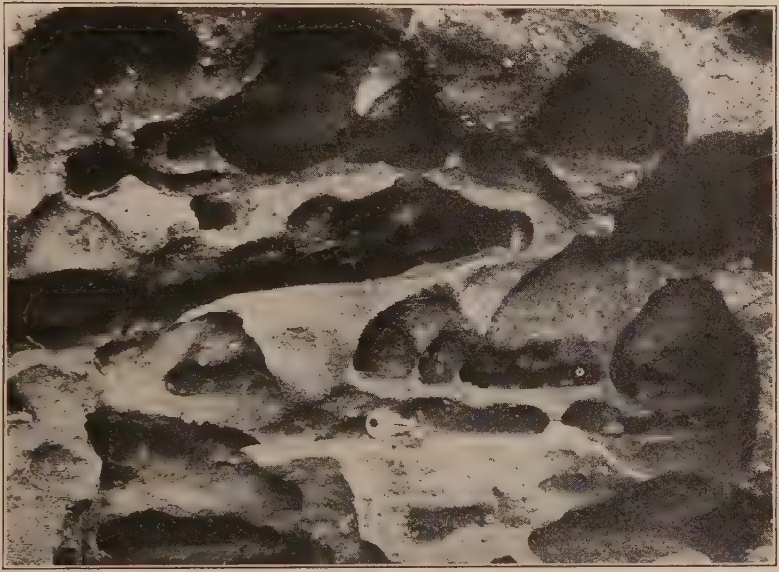

Plate XII. ERODED POTTSVILLE CONGLOMERATE.
Where the conglomerate and sandstone contain a stronger cementing material, they have resisted erosion while the weaker portions have weathered away. Comparative sizes of objects shown by key.

the Onondaga thins out. South of the more southern of the favorable exposures described, it is under cover.

The Ohio shale of the Devonian has been used for surfacing the roads. It breaks down, however, in wet weather into a sticky mud, and in dry periods is dusty. Limestone is far superior for road material.

The Mammoth Cave limestone of the Mississippian offers an abundant supply of ballast and road metal. It has been used on the main roads near the outcrops, and in the construction of the dam for the Pigg Hollow Reservoir.

Layers in the Gasper oolitic limestone, and perhaps some of the other adjacent limestones, can doubtless be found which are pure enough to be used in the manufacture of lime and cement. Agricultural lime can be secured especially from the purest oolitic beds of the Ste. Genevieve and Gasper.

Plate XIII. EAST PINNACLE.

View from Narrow Gap looking northeastward. The gray cliffs, 130 feet high, are of Mammoth Cave and Gasper limestone. The darker formations at the top are Pottsville conglomerate. Indian Fort Mountain lies across the notch to the left.

The Wildie sandstone occurs in the higher knobs. It is suitable for building stone, culverts and the like.

A few small quarrying operations have been carried on near Berea. A sandstone quarry was once opened south of Berea toward Boone's Gap near the Louisville & Nashville Railroad. It furnished building stone, abutments, piers, culverts and curbing. Mammoth Cave limestone has been quarried for road metal from Miss E. K. Corwin's farm along the road leading from the Dixie Highway eastward to the Big Hill district. It has also been quarried from near the top of the knob just south of Berea. A small quarry in the Onondaga limestone is situated near Middletown, north of Berea. Small quantities of rock have been excavated for various purposes along the Dixie Highway from Berea to Richmond, and at other localities. Berea College has a quarry in the Onondaga limestone a few hundred yards north of the L & N. depot at Berea. Berea.

Coal. A bituminous coal seam, 24 to 30 inches thick, occurs near the bottom of the Pottsville formation. On Bear Mountain this seam is geologically sixteen feet above the top of the Rockcastle conglomerate. Only a small acreage at the crest of this knob is high enough to catch the coal. The outcrop is covered. A drift was driven into the side of the mountain to the unweathered coal. The seam near the entrance to the drift is now badly weathered, and part of the roof has fallen, breaking the mine timbers. This wagon mine was never of much importance. The coal was hauled over rough, steep trails to the Dixie Highway about 500 feet vertically below the mine. Only a very high price for coal will make the mining of this coal a paying investment. A continuation of this seam may occur in the Pottsville of the high knob just south of Bear Mountain. The two knobs are connected. Coal might be looked for in the sandstones and shales overlying the Rockcastle conglomerate, when present, in other knobs of the Berea Region. In some localities to the southeast, a sandstone occupies the horizon of the conglomerate and the coal lies above the sandstone. Coal mining, however, never will be of importance in this area.

The same interconglomerate coal seam, 24 to 30 inches thick, is actively mined at Big Hill on the border of Madison and Jackson Counties, where the Eastern Kentucky Mountains come in contact with the Knob Belt. The drift mines are small. The coal is sold locally and also hauled by wagon to Berea, where it is marketed.

Oil and Gas. Oil and gas occur in the Onondaga and Niagaran limestones in the Berea Region. Oil seepages are noted in the brooks along the outcrops of these formations just north of

Berea. Oil and asphalt seep from the limestones near the crest of an anticline where a creek flows across the road near the schoolhouse by the Berea Fair Grounds.

A number of shallow wells around 125 feet deep, starting in the Ohio shale, have found oil and gas on the Snyder farm near Slate Lick, southwest of Berea. The structure is anticlinal, the long axis of the fold extending in a general northeast-southwest direction. Cross-folds occur along the major anticline. Gas was struck, and oil reported in wells drilled at Boone's Gap. A small quantity of oil was found by drilling west of Berea toward Wallaceton. South of Berea off the Dixie Highway a well is said to have been drilled in the vicinity of Dr. J. W. Raine's farm. A showing of oil was reported. A deep well was drilled near the Berea College barns. It was said to have yielded salt water. A gas well was drilled near where the road to Owsley Fork Caves leaves the road to Big Hill. A smaller gas well and two practically dry holes are reported in the vicinity of Pilot Knob. Two wells, said to have a showing of heavy black oil, were drilled, one on either side of the road from Big Hill to Bobtown, near Mat Moody's old store. These two wells are too near the outcrop of the Onondaga and Niagaran limestones. A dry hole was drilled a short distance south of the Dixie Highway bridge over Silver Creek just east of Berea. This hole is too near the outcrop of the Onondaga and Niagaran to obtain oil from these formations. It is said to be somewhat over 400 feet deep. A dry hole was drilled at Blue Lick. None of the wells in the Berea Region are producing oil. The structure in all cases is anticlinal where oil and gas were found.

Outside of the Berea area in Jackson County the extension of the Station Camp oil pool is advancing toward the southern portion of the Berea Region.

Rock structures favorable to the accumulation of oil and gas occur at several places in the Berea area. The Joe Lick-Combs Mountain fault and fold and its westward continuation of faults and folds to near Wallaceton have been described in this report under the topic of Structure. Prospecting should be carried on some distance south of the Onondaga outcrop if production is desired from this oil "sand." If drilling is started in the valleys, only shallow wells will be necessary to reach the Onondaga and Niagaran limestones. Before drilling, however, the structure should be carefully worked out.

Oil Shale. The petroleum accumulations of the United States will probably be practically exhausted during the lifetime of the younger generation and their children, provided the present rate of production and development of new territory is continued. Great quantities of oil at present are being imported into the United States from Mexico and other countries. But even the foreign fields will ultimately cease to yield. When the oil wells go dry substitutes will have to be found to take the place of the products obtained from crude petroleum.

An enormous potential reserve is found in the black oil shales of Kentucky and several other States. The oil shale contains little or no liquid petroleum but it does have bituminous substances. When quarried, crushed, placed in a retort and subjected to destructive distillation, it yields gas, crude oil, and nitrogen compounds. The gas is used to heat the retort, and if a large excess is produced, can be sold for illuminating gas and other purposes. The crude oil is refined and produces numerous petroleum products. Ammonium sulphate is one of the many chemicals that can be manufactured from the nitrogen compounds. The shale residue will be utilized economically.

Oil shale occurs in enormous quantities in the Berea Region. Berea is built on a ridge composed of oil shale and the valleys and the base of the knobs to the east, south and southwest of Berea for several miles, are made up of the Ohio oil shale. Little or no stripping of the overburden would be necessary at the majority of locations. Silver and Brushy Creeks could furnish the water necessary for the operation of oil shale plants. Transportation by rail is near at hand. The oil shale outcrops along the Louisville & Nashville Railroad for a few miles south of Berea after which it dips beneath the Waverly formations.

Ohio shale in Madison County, where tested, had a specific gravity of 2.047, weighed 127.50 pounds per cubic foot, and produced 18.5 gallons of oil and 8,000 cubic feet of gas per short ton of shale. Shale quarried at a greater depth below the surface than that from which the samples analyzed were obtained, should have an oil and gas content higher than the figures here given.[1]

The development of Kentucky oil shales does not appear economically possible at the present moment, but as better methods of treament are discovered and the prices of petroleum products increase, the oil shales will become of value. A successful oil shale plant, however, will have to be operated on a large scale by thoroughly competent engineers, chemists and business men. Ultimately the Ohio oil shale will be a source of tremendous wealth to the individual citizens of Kentucky and to the State.

WATER RESOURCES.

The water resources of the Berea Region may be divided into (1) surface water, (2) ground water.

(1) The streams of the area have already been described. They are of value in furnishing water to live stock. Brooks also help feed the Pigg Hollow Reservoir which is one of the chief sources of water supply for Berea.

(2) The underground water supply is effected by the character of the bed rock. The water resources of the various formations, considered in ascending geological order, briefly, are as follows:

If a deep well in the Berea Region is ever drilled to the Calciferous formation, it will in all probability yield salt water or salt-sulphur water.

The Richmond limestone furnishes water, usually containing magnesia.

The Silurian and Devonian limestones yield water for the use of the farmhouses. The water is hard and contains magnesia, calcium, and other salts. Several springs flow from the Onondaga along its contact with the underlying blue shale.

The Ohio shale is rather impervious except for the systems of joint planes which occur nearly at right angles to each other. These joint planes permit the water to seep into the formation. The water occurs chiefly in the joint planes which decrease in size downward. Many springs occur along the outcrop of the Ohio shales. Some of these springs are highly mineralized, the water having obtained its mineral content from the pyrite concretions scattered through the shale. Sulphur, alum, chalybeate and other mineral waters flow from this formation. In the Berea Region, sulphur springs occur at Slate Lick, Blue Lick and elsewhere. Some wells in the Ohio shale are around 50 feet in depth, others more shallow. Sulphur water is usually obtained.

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[1] For detailed account of oil shale in the Kentucky Knobs, see Jillson, W. R., Economic Papers on Kentucky Geology: Ky. Geol. Survey, Series VI, Vol. II, 1921; and Burroughs, W. G., Geography of the Kentucky Knobs: Ky. Geol. Survey, Series VI, Vol. XIX, pp. 74-78, 1926.

Plate XIV. PIGG HOLLOW.

Scene three miles southeast of Berea, looking south. About one mile up this hollow a concrete dam has been built across the valley forming a reservoir from which Berea obtains the greater part of its water supply.

Wells are in danger of contamination, for due to the circulation of water through the joint planes disease germs may be carried for some distance without the water being purified.

The Waverly formation's steep slopes on the face of the knobs cause the surface run-off to be greater than on the more gently inclined strata. Especially is this true of the rather impervious Waverly shales and clays. Soft water is obtained from Waverly sandstone from which springs issue in several places. The Wildie sandstone is one of these strata furnishing water.

The Mammoth Cave limestone is quite soluble and frequently contains underground passages and caves throughout the

Berea Region, for example, at Big Hill, Owsley Forks, Indian Forts and Cow Bell Hollow district. Stalactites and stalagmites have formed by deposition from the water in the caves. Springs occur within the caves and issue from the formation at various points. Berea obtains part of its water supply from springs in the Mammoth Cave limestone, the water being piped to town. The water is hard. The springs and Pigg Hollow Reservoir are owned by Berea College.

The sandstone and sandy soils of the Pottsville formation readily absorb rain water. Some springs occur in this strata. Such a spring is found in the northern end of the Indian Fort Mountain and was probably used by the prehistoric defenders of the fort.

Plate XV. BASIN MOUNTAIN, A PREHISTORIC STRONGHOLD. The entire top of this knob is within the "fort." Where the gray limestone cliff is broken to right center of the illustration, a stone barricade 465 feet long still guards the entrance to the crest. Scene looking north. This stronghold was discovered by the author, W. G. Burroughs.

Special Physiographic Features.

Caves are of frequent occurrence in the Mammoth Cave limestone. Some caves contain two or more levels. Stalactites and stalagmites are found. The location of a few of the caves is as follows: The low entrance to a cave occurs in the limestone cliff beside the road part way up the Big Hill; there are small caves in the limestone in Indian Fort Mountain and nearby knobs; caves occur in the vicinity of Cow Bell Hollow, and to the south of Bear Mountain. Caves in Basin Mountain prehistoric fort often contain pits 170 feet in depth. Outside of the Berea Region are the Owsley Fork Caves on the creek of that name, the Brushy Creek caves to the south of Berea, and caves in the limestone of the Bluegrass.

Sink holes, several of large size, can be seen in the Mammoth Cave and Gasper limestones at the head of Pigg Hollow.

Rockhouses are numerous in the Indian Fort Mountain. They are recesses in the face of the Pottsville conglomerate and sandstone, formed by the more rapid weathering away of the layers where now are the interiors of rockhouses, than occurred in the overlying beds. A number of these rock houses that face the sun, were used as places of burial by the prehistoric inhabitants. The author, during his survey of the Indian Fort for the Kentucky Geological Survey, discovered and investigated these ancient remains.[1]

Plate XVI. PILOT KNOB.

Bottom-land on Ohio shale, Waverly strata forming slopes from near the base of knob to the gray cliffs of Mammoth Cave and Gasper limestone. Scene looking eastward in Madison County.

Prehistoric mounds constructed by the former inhabitants of the region occur to the north and west of Berea in the rolling knob land. A mound on the top of a high knob of Ohio shale of the J. D. Clarkston farm just north of Berea, was investigated by the author. It contained, near the top, an eight-inch layer of charcoal in which were many bones, doubtless the remains of a sacrifice. Deeper in the mound were two layers of rock between which was clay. In this clay were human bones and teeth. Four copper plates, used as armor, were found in the grave. Beneath the lower rock layer and clay was another bed of charcoal which rested upon clay.

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[1] An account of this exploration is given in "The Geography of the Kentucky Knobs," by W. G. Burroughs, Series VI, Vol. XIX, of the Kentucky Geological Survey.

The knobs form "outliers", with young strata on their tops and older strata, usually Ohio shale, in the valleys at their bases.

Stream features occur, such as meander curves, rapids, waterfalls, and the like. The topography has already been described.

Excursion to Bear Mountain.

The geologic and physiographic features that can readily be seen in a trip from Berea to Bear Mountain, are as follows:

Remnant of Lexington peneplain—ridge at Berea.

Ohio shale—This is an oil shale strata, Devonian System. Forms bed rock in valley from Berea to the base of Bear Mountain.

Joints and bedding-planes—Brushy Creek at Dixie Highway bridge.

Stream features—Brushy Creek and stream opposite Normal Model School.

Waverly shale, Mississippian System—lower slope of Bear Mountain. Exposed along road leading up the knob.

Geodes and concretions—along road and in the Waverly formation.

Quartz crystals—in geodes.

Sandstone—part way up knob.

Unconformity—north side of trail at contact heavy sandstone and soft shale New Providence.

Spring—after passing cabin on saddle between Bear Mountain and knob to the north.

Wildie sandstone—at spring.

Warsaw siliceous limestone—just beyond gate after leaving spring.

St. Louis limestone—to left of road just above Warsaw limestone.

Chert and coral—in St. Louis limestone.

Ste. Genevieve oolitic limestone—above St. Louis.

Crinoid fossils—in limestone fragments near peach orchard.

Chester strata—mostly covered, but a few outcrops occur above the Ste. Genevieve.

Bituminous coal seam.

Rockcastle conglomerate, with cross-bedding—on south slope of knob. This is a river channel filling.

Formation of knobs, V and U-shaped valleys, mature and old topography—viewed from Pottsville strata of the Pennsylvanian System—top of Bear Mountain. Knob Belt, with Lexington peneplain, (Bluegrass), to the north.

Excursion to Pinnacles and Indian Fort Mountain.

Lexington peneplain—ridge at Berea.

Ohio shale, Devonian System—forms bed-rock to base of the Pinnacles.

Joints and bedding planes in Ohio shale—bed of Brushy Creek, seen from bridge on Prospect Street, Berea.

Stream features—Brushy Creek.

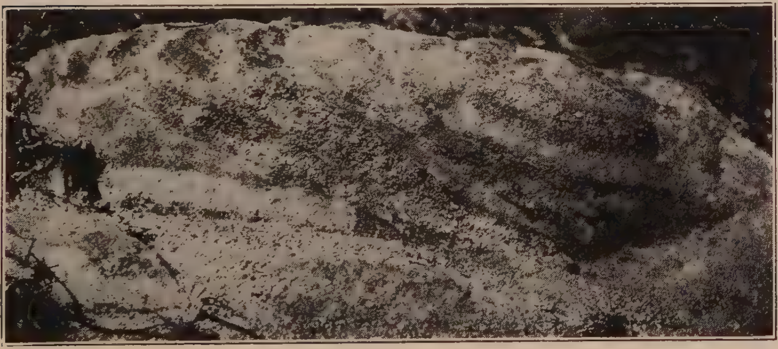

Plate XVII. CROSS-BEDDING IN POTTSVILLE CONGLOMERATE. Outcrop on trail leading from Narrow Gap to Indian Fort Mountain. Thickness of bed, three feet.

Knobs.

Waverly shale—forms lower slopes of Pinnacles.

Concretions and geodes—in Waverly.

Chert and coral—in Mammoth Cave limestone.

Mississippian formations through the Gasper, as described for Bear Mountain, outcrop on knob-slopes up to Rockcastle conglomerate, Pennsylvanian System.

Pottsville conglomerate, sandstone and shale—caps the Pinnacles, Dome and Indian Fort Mountain.

Unconformity between Mississippian and Pennsylvanian—at contact of conglomerate and limestone.

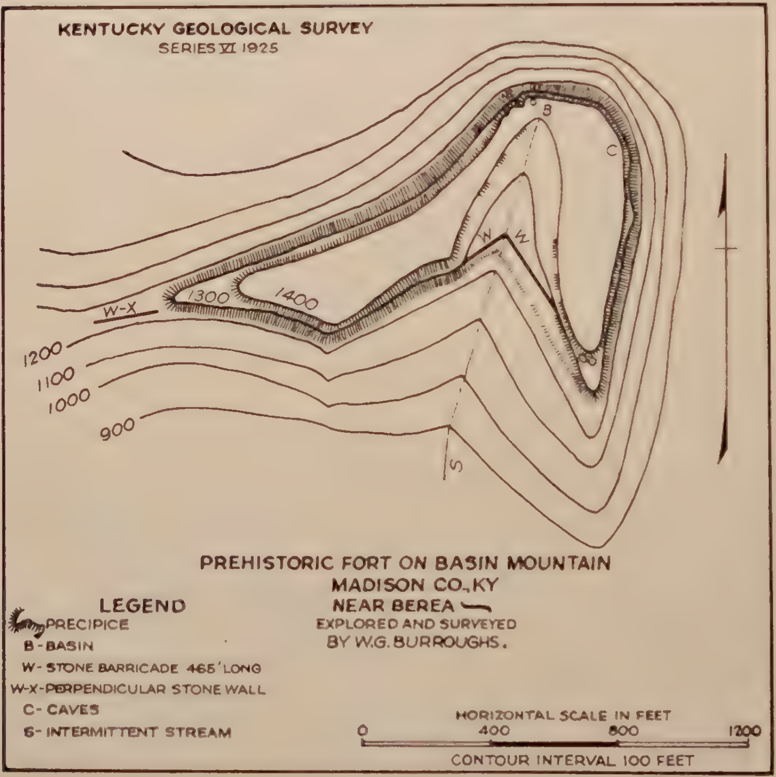

Plate XVIII. MAP OF THE PREHISTORIC STRONGHOLD ON BASIN MOUNTAIN, MADISON COUNTY.

Large joint planes at Indian Fort Mountain—Examples, Devil's Slide, Fat Man's Misery.

Rockhouses—in Rockcastle conglomerate.

Cave in Mammoth Cave limestone—on east side of Indian Fort Mountain.

Cross-bedding of conglomerate—in road below abandoned quarry, Indian Fort Mountain.

Sand and gravel quarry in Rockcastle conglomerate—Indian Fort Mountain.

Ripple marks in Pottsville sandstone—in narrow path leading to north end of Indian Fort.

Topographic features—seen from top of Pinnacles, same as Bear Mountain.

View of Lexington peneplain—from West Pinnacle, or at the Bungalow.

Beautiful knob scenery—from East Pinnacle, or crest of cultivated field, northern end of Indian Fort. Cumberland Plateau on eastern horizon.

Numerous prehistoric stone walls, barriers and stone ''ammunition'' piles—as mapped and defined in ''Geography of the Kentucky Knobs,'' by W. G. Burroughs, Ky. Geol. Survey, Series VI, Vol. XIX, for both Indian Fort Mountain and Basin Mountain forts.

Prehistoric graves in rockhouses of Indian Fort Mountain—below the barn facing Chestnut Hollow, and in rockhouses facing eastward toward Pilot Knob.

Newly discovered prehistoric fort and caves on ''Basin Mountain,'' to north across deep valley from cultivated field of Indian Fort Mountain. Dangerous pits in certain of these caves.

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22. Topography of Madison County shown on the Richmond Quadrangle. Scale, 1:125,000, Contour interval 100 feet. Surveyed in 1890.

COALS OF
MARTIN COUNTY

BY

James S. Hudnall
Assistant Geologist

COALS OF MARTIN COUNTY, KENTUCKY

By
J. S. Hudnall
Assistant Geologist

Location and Field Work

Martin County is located between Levisa and Tug Forks of the Big Sandy River, and the Kentucky and West Virginia line. It lies south of Lawrence, east of Johnson, northeast of Floyd and north of Pike Counties in Kentucky; west of Mingo and southwest of Wayne Counties in West Virginia.

The field work for this report was done from July 18 to September 21, 1921. The topographic sheets of the United States Geological Survey, scale 1:62500 were used as base maps in this survey. The purpose of the survey was to work out the structure of the county, and determine as nearly as possible its oil and gas resources. Inasmuch as the working out of the structure could best be accomplished by leveling on the coals, it became necessary to make some detailed study of the coals of the area, and correlate them over the county. The elevations were run principally on the Peach Orchard seam with aneroid, checked on spirit level elevation. Hence the elevations given in the sections may be subject to from 10 to 25 feet error.

Topography and Stratigraphy of Coals

Martin County occupies a unique location in regard to the stratigraphy of eastern Kentucky, lying as it does between the Levisa and Tug Forks, and on the Kentucky and West Virginia line. Hence a correlation of the coals across the county will correlate the coals of two basins, the Tug Fork coal basin and the Levisa Fork coal basin. At the same time, the West Virginia coals and Kentucky coals will be correlated.

Topography

Martin County has very much the same type of topography as her sister counties, Lawrence, Johnson, Floyd and Pike. The lower or north end of the county is made of steep hills rising

400 to 500 feet above the Rockcastle Creek, which is the largest and most important stream in the county. There is but little level ground in the county, that being limited to the northern end, along the Rockcastle Creek, which has entrenched itself in the Pottsville shales and sandstones depositing a very pure white sand several feet thick over its valley. On the headwaters of the creek the streams have but little or no level ground in their valleys. The bottoms of the streams are usually solid rock, and the valleys very narrow, thus lending themselves to the building of dams across their courses to hold back the water till time of flooding, when all the dams are opened, and the logs which are brought to the water courses during the summer are floated down the creek to Tug Fork, on to Catlettsburg and Ashland, where they are sawed and manufactured into lumber. The heads of the creeks are much rougher than the lower parts. The sandstone cliffs are very continuous for miles along the water courses. Along the Martin County line adjacent to Johnson, Floyd and Pike Counties, the divides rise from 1,500 to 1,600 feet above tide, and from 700 to 800 feet above the streams. Most of the topographic features are expressive of the rocks underlying the soil or exposed along cliffs. There are two or three very distinct horizons which form steep if not precipitous cliffs along the mountain sides. Thus the East Lynn conglomeratic sandstone forms cliffs 50 to 70 feet high along the Martin and Johnson County line and along the Martin and Lawrence County line. In places, this same ledge may be seen forming high cliffs on the head of Middle Fork, between Johnson and Martin Counties. Just below this coarse sandstone there is usually a broad bench, where springs are very abundant, marking the horizon of the Richardson coal.

Another prominent topographic feature is the cliff, 40 to 60 feet high, occurring about 100 feet below the above one. This cliff marks the horizon of the Homewood sandstone of the West Virginia Geological Survey. From 40 to 60 feet below this cliff there is the most persistent sandstone cliff in the entire county. It is usually 70 to 100 feet high, and of a grayish white color. On top of this sandstone cliff the Peach Orchard coal is usually found. This cliff can be traced in continuous outcrop from Wolf

Pen Fork, where the Peach Orchard coal is well developed, to the head of Middle Fork, where it goes under drainage. Two of the outstanding features of the topography in Martin County are Flag Knob on the head of Cassady Branch of Coldwater and Big Crooked Branch of Wolf Creek and Chestnut or Spring Knob on the head of Meathouse Creek. The first of these knobs has had the underbrush cut away, and an observation platform built, from which one can get an excellent landscape view of the county. The elevation of this knob is something over 1,350 feet above sea level. The second knob is the highest point in the county. It rises from 720 feet above tide at the base to 1,600 feet at the top. Both of these prominent features are capped by the Allegheny Series, doubtless the East Lynn conglomeratic sandstone has added to their height by resisting weathering.

GENERAL GEOLOGY AND STRATIGRAPHY

The rocks exposed in Martin County are all of the Pennsylvanian System, and mostly of the Pottsville Series. However, the tops of the highest knobs have several feet of Allegheny on them. All of the coals below the Richardson of Crandall[1] belong to the Kanawha Series of the West Virginia Geological Survey. On the chart of sections will be seen a general section of the county, starting with the Warfield coal. The Warfield coal is the lowest horizon exposed in Martin County, with the exception of about 30 feet of shale exposed below the Warfield coal on Buck Branch of Wolf Creek. From looking at the general section, it will be seen that there are several commercial coal seams in the county. A brief description will be given of the coal seams and their correlations made as worked out during the field work for this report. Nothing below the Warfield seam will be discussed, as this is the lowest coal horizon exposed in the county.

The Warfield coal is above drainage in only one locality in Martin County. Along Tug Fork from Stonecoal to Kermit and on Buck Branch of Wolf Creek, the coal is brought above drainage by the Warfield anticline, but it soon goes under drainage about the mouth of Wolf Creek, where the steep dips from the fault and anticline carry it down to some 250 or 300 feet below drainage. This coal has been diamond drilled in almost every locality in the county, and the reports indicate that it is a very persistent horizon. There is some doubt as to the identity of this coal with the VanLear coal, a correlation made by Prof. Crandall several years ago. The Van Lear correlates with the upper Marrowbone. The Warfield has been correlated with the Pond Creek by the West Virginia Geological Survey and Professor Crandall. The Pond Creek certainly correlates with the lower Marrowbone. This coal is also approximately 320 feet below the Fossil Limestone, or the limestone occurring 80 feet above the fire clay coal in Johnson, Magoffin and Martin Counties.[1] Prof. Crandall identifies a coal on Ash Branch of Wolf Creek as perhaps the Warfield coal; however the fossiliferous limestone is found here at an elevation of about 60 to 80 feet above the creek, hence the Warfield coal would be over 200 feet under drainage. The Wolf Creek syncline carries the coal down some 250 to 300 feet here, and the coal which he identifies as the Warfield is his No. 3 coal of Middle Fork Section in same report. It is not surprising to see that the analysis of the coal does not correspond with that of the Warfield vein. There is a thickening to the southeast of the upper Pottsville Series of several feet per mile. The interval between the Richardson coal and the Warfield coal at a point seven miles below Naugatuck near Stonecoal is 594, while at Naugatuck the interval is 777, a thickening of 27 feet per mile. The distance from Peach Orchard to Ash Branch is 14 miles, and in a parallel direction from the above places sighted, hence the interval between the Richardson coal and Warfield coal would be increased 378 feet. Likewise, the interval between the Warfield and Peach Orchard would be increased approximately 250 feet. The failure to take into account this factor leads to a false conclusion as to the identity of coals.

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[1] Ky. Geol. Survey. Bull. No. 4, Coals of Big Sandy Valley, p. 18, 1905.

In ascending order, the next coal of any commercial importance in this area is the Alma of West Virginia, coming from 100 to 120 feet above the Warfield. This coal is sometimes three feet thick in the southeastern end of the county, but is not developed in the north end of the county. It is under drainage in most of the county, coming above drainage only where the Warfield anticline has brought it up.[1] The Alma coal does not correlate with the Peach Orchard seam as has been done heretofore. The coal is very near the horizon of, and perhaps correlates with the Jenkins coal (Elkhorn No. 3 of Floyd County).

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[1] Ky Geol. Survey, Bull No. 4, 1905, p. 45.

At an interval of 150 to 185 feet above the Warfield seam is the Williamson coal. It has a thickness of about 36 inches at Nolan. The only places opened in the county are along the Tug Fork from Nolan to Naugatuck, where it goes under drainage. It is of but little importance as a coal producer in Martin County. Above the Williamson coal from 20 to 40 feet comes the Dingess coal, which is best developed in the Nolan district and the southeastern part of the county. It too, is under drainage in most of the county, and is of but little commercial importance. The Hernshaw coal of the West Virginia Survey is found about 30 to 40 feet above the Dingess. Its commercial area is limited to the southeastern part of the county, though small blooms of all three of these latter coals may be seen on the Middle Fork road about two to six miles above Inez. They are also seen along the road from Inez to Kermit on Blacklog, where the Paintsville uplift has brought them above drainage.

The Fire Clay coal is the next coal of any importance in the county. It lies about 240 feet above the Warfield coal, and is well developed on Pigeonroost Creek, where it is 30 to 50 feet above drainage. It is also seen in the bed of the creek along Petercave Creek at Three Forks, where it occurs under a well developed sandstone. On Big Branch of Brushy Creek, in Pike County, it is also well developed showing five feet of coal in some places. Throughout the northern end of the county it is below drainage. This coal is correlated with the lower Chilton of West Virginia. The next coal in ascending order of the series is the Upper Chilton of West Virginia, and the B coal of Crandall's Middle Fork section. This coal lies about 300 feet above the Warfield vein, and perhaps corresponds with the Limestone coal, as it is usually 30 to 60 feet above the Fire Clay.

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[1] Ky. Geol. Survey. Report of Progress, 1908-09, p. 45.

The Hazard Coal: This coal is one of the most persistent horizons in the county. It often has brachiopods and crinoids in the roof of the coal. This coal is perhaps the easiest recognized of any in the county, because the marine fossils can often be found, and the black, sometimes fissile shale roof rock is present in most cases. This coal is about 36 to 55 inches thick, and has been opened very extensively along Pigeonroost Creek, where it is about 40 to 80 feet above the creek. It is the coal which is extensively used for domestic purposes on Pigeonroost, lower Petercave, upper and middle Wolf, Meathouse, and upper Middle Fork. The same vein has been opened on the head of Saltwell of Middle Fork. This is as far north as it was traced, but it is perhaps the coal opened on upper Alpha Branch, about the level of the branch. It is the coal Crandall called the Warfield on Ash Branch of Wolf Creek. About 60 feet above this coal lies the Buffalo Creek coal of West Virginia and the 2A coal of Crandall in his Middle Fork section. This coal is from 36 inches to 48 inches thick. Its bed section usually shows a streak of bone coal, and rarely, a shale parting of two to four inches. Openings have been made on the head of Emily Creek about ¼ mile up a right hollow of Low Gap Branch. Another opening has been made on the head of Main Emily, where the coal was used to fire the engine on a tram road in marketing the logs of that section. The coal has been opened several times on the head of Long Branch, and near the mouth of Long Branch on Tug Fork. Extensive openings have been made along the Middle Fork from Beech Fork to the head. This coal, like the others described above, is best developed in the southeastern part of the county. This vein, however, has received but little attention from the prospector, and its true thickness is not known in enough localities to determine definitely its economic importance. It had a sandstone roof in most every case, those opening on Middle Fork and Scaffolick being the only exceptions, where there was a few feet of slate coming in between the coal and the sandstone.

Above the Buffalo Creek coal, comes the Massive Lower Peach Orchard sandstones, which forms cliffs from 60 to 100 feet high, on top of which comes the Coalburg coal, which is corre-

lated with the Peach Orchard coal of Lawrence County. The interval between the Peach Orchard Coal and the Warfield or No. 1 increases a great deal as they are traced southeast across Martin County. Thus near Peach Orchard, on the Martin and Lawrence County line, the interval is approximately 350 to 400 feet, while on the Martin and Pike County line, at the head of Big Branch of Brushy Creek, it is approximately 600 feet, perhaps more, while at Chattaroy the interval is 730 feet according to the West Virginia Geological Survey. The Peach Orchard coal is perhaps the most persistent coal in Martin County. It runs from 0 to 140 inches in thickness, usually being about 96″ with several streaks of shale from 1 to 3 feet thick. It more often has a blue shale roof of 10 to 20 feet thick, extending to the massive sandstone overlying it. Its topographic position is usually half way up on the mountain side, but on the head of Middle Fork the Wolf Creek syncline has brought the coal down to the level of the creek. At Rachel DeLong's on the head of Linnbark of Coldwater, the branch runs along on the coal for almost a mile. The coal is so thick, and has so much shale associated with it, that it most always forms a broad bench; often there is so much water associated with it, that swamp grass may mark its bloom. It may be found almost anywhere in the county by going up the branches, noting the 100 feet of sandstone just below it, which usually shows up in the bottom of the branch. At the top of the sandstone there is usually a damp place, if not running water, where swamp grass, or perhaps ferns, grow. This coal is one of the easiest horizons in Martin County to recognize, and should be a good guide to prospectors who wish to open the coals. There is so much water associated with this coal, and it is so easily found, that the hogs which run at large use it for their watering place, often rooting out large lumps of it in searching for the mineral matter it contains. This coal is frequently not commercial, due to its having so much rotten shale in it, and such a proof roof, though it is 10 to 12 feet thick with only 4 to 9 inches of shale in it. Occasionally it has a sandstone roof. In places a rider develops to a thickness of 3 to 5 feet. It lies from 10 to 35 feet above the Peach Orchard. This coal correlates with the famous No. 6 Hazard of the Hazard Coal Field.

The Stockton coal of West Virginia, which correlates with the Broas coal of Crandall is the next most commercial coal in ascending order. It occurs from 60 to 100 feet above the Peach Orchard, and is one of the finest coals in the county. This coal is well developed in all the southeastern end of the county, covering a large area where the Wolf Creek syncline has brought it down. It more often occurs in about 40 to 50 feet of light shale, but frequently has a splendid sandstone roof. This coal runs from 4 to 7 feet thick, and seldom has more than 2 to 5 inches of shale parting in it. In texture this vein is a splendid block coal, especially the lower three feet of the bed. The upper two feet is semi-splint. This coal has not been opened in the northern end of the county as often as the Peach Orchard seam, the most prospected seam in the county. It is opened in a few places around Tomahawk, where it shows about 4 feet of coal. The bloom of this coal shows in most every section in the county, showing that it is very persistent, and is found elsewhere than in the Broas Field on the head of Middle Fork, where it was first prospected. This coal underlies a great deal of territory in the northern end of the county, where the structure is low. It is well worth prospecting in the region of Lick Branch of Rockcastle Creek. From 20 to 30 feet above this coal comes one of the most important stratigraphic horizons in eastern Kentucky. It is the Homewood sandstone, which is a coarse sandstone approximately 100 feet thick. It breaks down in large blocks and is very massive. The beds are from 10 to 20 feet thick in places. This is perhaps the Puncheon Creek sandstone of Browning in Magoffin County. The name of the Homewood sandstone was taken from the West Virginia Geological Survey, which has done a very detailed piece of work from Kenova to Matewan on Tug Fork. The Homewood has heretofore been identified as the sandstone which overlies the Fire Clay coal. However, in tracing this horizon through to the Kentucky-West Virginia State line it was found to lie 350 feet to 400 feet below the Homewood sandstone of the West Virginia Geological Survey. This sandstone marks the top of the Pottsville Series, wherever it may occur, as it was taken as the top of the Pottsville Series in the type locality of Pennsylvanian. The Homewood sandstone as identified by the West Virginia Geological Survey is placed at the top of the Pottsville Series in this report. The reasons for placing the division between the Pottsville and Allegheny at this horizon are based upon previous reports on the subject. Thus David White, in Bulletin 348, U. S. G. S., page 30, places the Peach Orchard coal as undoubtedly in the Pottsville Series. Also the sandstone series, 100 to 200 feet thick, which overly the Peach Orchard seam, are Pottsville.

Since the Fire Clay coal underlies the Peach Orchard seam, 150 to 200 feet, the top of the Pottsville must be above the Fire Clay coal. David White's divisions of the Pottsville and Allegheny is based upon paleobotanical evidence. Between this sandstone and the Richardson vein, about 60 feet below the latter vein, there is a coal about four feet thick, which has not been named in any previous report. It has been described in the West Virginia reports in adjacent counties as the Lower Clarion coal. This coal was not recognized in any section of the county other than the Stafford Fork locality. Crandall recognized the vein, but did not name it. For convenience it is here called the Lower Clarion vein. It is a commercial coal on Stafford Fork, but has been opened in only a few localities. Above this vein is the well known Richardson vein, which has been mined on the head of Stafford Fork and the head of Middle Fork. In fact, it has been opened all along the Martin and Lawrence County line from Wolf Pen Branch south. Openings have been made also along the high ridge between Martin and Johnson Counties. Crandall called it the "Broas F" vein. It sometimes carries a foot or two of semi-cannel coal. Large sheets of cannel coal, sometimes two or three feet in diameter, are seen in the gaps where they have come from the coal higher in the knobs. This coal sometimes has a thickness of 13 feet, with 2 or 3 feet of shale parting; it commonly runs about 4 feet of coal, 2 feet of shale, and 5 feet of coal. In the northern part of Martin County, where the dip has brought it down, this coal underlies a large per cent of the area. It has not been opened in many places outside of the localities mentioned above, but it undoubtedly occurs in a great deal of the lower end of the county, and along the Wolf Creek syncline. The horizon of this coal is usually marked by a broad bench and many springs. It is called the No. 5 Block coal of West Virginia, but does not seem to be as well developed in thickness there as in Martin County. Openings in this vein have been made at Naugatuck on the M. H. Waldron farm, where it is reported to be 5 feet, with some shale partings. This coal is the base of the Allegheny Series, according to the West Virginia Geological Survey, which seems to correlate with David White's divisions of the Pennsylvanian. Above this coal comes the East Lynn conglomeratic sandstone, which is 50 to 80 feet thick, and caps the dividing ridge between Johnson and Martin, and Lawrence and Martin and Lawrence Counties. This sandstone often has very white well rounded quartz pebbles ¼ of an inch to 2 inches in diameter. These pebbles may be found on most of the high points in the county, and often in the low gaps, and less frequently along the water courses. The conglomeratic phase is best developed on the head of Stafford Fork of Rockcastle Creek. This sandstone is a splendid horizon marker, and serves as a check on the coals wherever the mountains are high enough to catch it. Dr. I. C. White provisionally correlates it with the lower Freeport sandstone of western Pennsylvania. There is usually a thin band of iron ore at the base of this sandstone near the Richardson coal. On top of Chestnut Knob on the head of Meathouse there is some 200 feet of Allegheny measures exposed, but no examination of them was made. There is also about 150 feet of rocks above the Stafford Fork conglomerate exposed on the head of Middle Fork, but no examination was made.

The following is a correlation between Kentucky and West Virginia coals. The West Virginia names are taken from Wayne and Mingo County sections given in the West Virginia Geological Survey reports of 1913 and 1914. The Kentucky names are taken from various reports.

Kentucky Names	**West Virginia Names**	**Magoffin Co. Names**
In Martin County		**By Browning**
Richardson-Broas "F."	No. 5 Block	Hindman
Interval 40 to 60 ft. Lower Clarion	(Top of Pottsville on top Homewood S. S. W. W. Va. To Potts.) Lower Clarion	(?)
Interval 60 to 85 ft. Broas "E" or Main Br.	Stockton	Fugate
Interval 60 to 100 ft. 3 Peach Orchard "D."	Coalburg	Hazard
Interval 100 to 140 ft. Local, King Fisher of Martin, at Inez	Winifrede	Young
Interval 40 to 60 ft. Coal "C" (2A) Rich'n Cannel by Crandall		Trace Fork
Interval 20 to 30 ft. Fossil limestone	Fossil Limestone (Not reported by W. Va. Geol. Survey, but found by author at Naugatuck, where the W. Va. Geol. Survey made a section and identified the coals.)	Fossil Limestone
Interval 20 to 30 ft. Limestone Coal "B" 2	Chilton "A"	Haddix
Interval 20 to 30 ft. Fire Clay Rider	Upper Chilton	Fire Clay Rider
Interval 30 to 40 ft. Fire Clay	Lower Chilton (?)	Fire Clay
Interval 40 to 60 ft. Locally called Creek Vein or Pigeonroost	Hernshaw (Local)	(?)
Dingess	Dingess	Whitesburg
Kendrick Shale, Limestone on Brushy Creek of Pike seen on Brushy at mouth of Mill Fork.	Dingess Limestone persistent horizon	Light fissile shale containing calcareous concretions and septaria.
Amburgy	Williamson	Gun Creek
Under drainage in Martin except at Warfield	Cedar Grove (Red Jacket Upper Thacker) Lower Cedar Grove (Lower Thacker).	Tom Cooper
Interval between Warfield and Fire Clay 240 to 320 ft. Place of Upper Marrowbone (Van Lear-Miller's Creek Coal)	Alma Campbell's Creek Limestone	Lacy Creek Coal. Mine Fk. Bastard Limestone.
Lower Marrowbone Warfield. (Freeburn)	Campbell's Creek Coal, Warfield No. 2 Gas	Wheelersburg

Note: The above correlation is essentially based upon a correlation of the limestones, with what other criteria present. Future work may modify the correlations somewhat, especially below the Fire Clay coal, for the coals below that horizon are exposed in only a few localities in Martin County. The correlation of the coals with the Magoffin County coals was made after a private interview with Mr. Browning, who worked that county in much detail, and who has traced the Fossil Gap Limestone to the Johnson and Martin County line, where it was identified and traced to Tug Fork. The striking feature in the correlation is the placing of the Homewood Sandstone, which marks the top of the Pottsville Series, 300 to 350 feet above the Fire Clay coal.

Some few detailed examinations were made in the field, and a summary of the same is given on the chart of sections. On these plates are figured almost every commercial coal exposed in the area, except the Warfield vein, which runs from 3′ to 5′, and is reported in almost every drill hole or oil well log in the county. Its good qualities and persistency are too well known to be discussed here. It is the most important vein in the county.

Evaluation and Commercialization.

The following table is given outlining the number of acres and tonnage of each coal in the county. Every known commercial vein is given which outcrops in the area, except the 4-foot vein called the Lower Richardson. It has only a local development, and was not considered. There are perhaps one or two commercial veins below the Warfield which were not taken into account. The figures given on the acreage and tonnage certainly are only approximate, and may be subject to a great deal of change as more prospects are opened. The value of the lower coals is perhaps slightly exaggerated, as they were under drainage in most of the northern end of the county, and their thickness could not be seen, and sufficient time could not be given to investigate many drill core tests. Hence the table at best is only approximate, but will serve somewhat as a guide to coal companies which may want to operate in Martin County.

Total in

Name of Coal	Thickness Assumed	Acres	Cu. ft. of Coal
Richardson	8	19,360	6,746,572,800
Lewiston & Stockton	4	41,161	7,171,892,640
Coalburg	5	65,858	14,343,872,400
Winifrede	3	82,323	10,757,969,640
Upper Chilton	3	98,787	12,909,485,160
Fire Clay	2	131,717	11,475,185,040
Dingess	2	164,000	14,287,680,000
Warfield	4	164,646	28,687,919,040
Total in Martin Co.	36	767,852	106,380,576,720

Name of Coal	Short tons 2,000 lbs.	Value at penny per ton
Richardson	274,250,927	$ 2,742,509.27
Lewiston & Stockton	291,540,351	2,915,403.51
Coalburg	583,084,203	5,830,842.03
Winifrede	437,315,839	4,373,158.39
Upper Chilton	524,775,820	5,247,758.20
Fire Clay	466,470,937	4,664,709.37
Dingess	580,800,000	5,808,000.00
Warfield	1,166,175,570	11,661,755.00
Total in Martin Co.	4,324,413,647	$43,244,136.47

TRANSPORTATION.

Martin County has no railroad in it at the present time, except about two miles built by the Himmer Coal Company at Warfield. The C. & O. Railroad runs within 4 miles of the Martin and Lawrence County line, and the Norfolk & Western runs up Tug Fork, along the Martin County line. Though the county has no railroad at present, the remotest place from a railroad is only about 18 miles. The roads in Martin County are below the average of the adjoining counties. There are only a few wagon roads in the county. These are limited to the larger creeks.

SUMMARY.

This report is very brief, due to the short time devoted to coal study while in the field. It is accurate in the major features but lacking in detail. From the table on the valuation of coals it will be seen that the county has an immense quantity of coal which has never been developed. Martin County occupies a unique place in the Eastern Kentucky Coal Field. It is low enough structurally to have the coals which are high in the mountains in the adjoining counties brought down near creek level until they cover a great deal of area, and it is far enough south and east to receive the benefits of the thickening of the Upper Pottsville Series as they extend to the south and east. Regional metamorphism has been sufficient to give the coals a high fixed carbon content in the southern end of the county. In general it may be said that the southern end of the county has better prospects for coal than does the north end, due to the fact that the mountains are 200 feet to 300 feet higher, and the coals thicken to the southeast with a thickening of the other members of the Upper Pottsville Series. Though the northern end of the county is lower structurally, and has more territory over the coals, the coals are not so thick or good in quantity. The northern end of the county has received but little attention from prospectors, and very few of the veins have been opened. A more thorough investigation may reveal some splendid coal in this section, especially in the Richardson and Peach Orchard veins. A few sections in the various parts of the county are given on the section chart which may aid the prospector in locating the coal veins. As a general guide to prospecting in the county, the following information may be helpful: The best horizon marker in the county is the Blue Fossil Limestone containing fossil brachiopods, crinoids, and occasionally mollusca. It usually occurs in a thin bedded shale about 40 feet thick. Once this is found, the Limestone coal may be readily found by examining 30 feet lower, and the Fire Clay coal 80 feet lower. Thirty feet above the limestone comes the Winifrede; 230 feet above the limestone comes the Peach Orchard, whose bloom may be recognized by being on a broad bench at the top of a cliff or very steep slope; 320 feet above the limestone comes the Broas, which is usually on a steep slope or a double bench; 395 to 450 feet above the limestone comes the Richardson coal. All of the above intervals thicken to the southeast.

A few coal companies have had their attention drawn to the richness of Martin County's undeveloped coal lands, and have prospected and purchased a large portion of the coal land. However, there are large areas of splendid coal land which offer unusual opportunity for development. At the present time there are no railroads for transportation, but it is only a matter of time until the industrial world will call upon Martin County for her coal; and the railroads will branch out to the remotest districts, transport her mountains of coal to the industrial centers.

ANNOTATED BIBLIOGRAPHY.

There has been but little published on the geology of Martin County. The bibliography here given is fairly complete, with the exception of a few references made to the county in other publications. The best publication on the coals of Martin County is ''Coals of Big Sandy Valley south of Levisa and between Tug Fork and headwaters of North Fork of Kentucky River,'' Ky. Geol. Survey, Bulletin 4, 141 pages, 30 pls., 1905, by A. R. Crandall. In this report he gives the following sections and analysis:

Peach Orchard Coal at Peach Orchard. **Dated 1905.**

	Upper 21 inches.	Lower 28 inches.
Moisture	4.52	3.00
Volatile combustible matter	34.68	35.60
Fixed carbon	56.80	57.80
Ash	4.00	3.60
	100.00	100.00
Sulphur	0.521	0.658

Section of Richardson Coal, head of Whitehouse Creek. Shale 2 ft. to 10 ft. to massive sandstone.

Coal	38″	Shale	6″
Shale	6″	Coal	22″
Coal	6″	Shale	2″
Shale	6″	Coal	12″
Coal	44″	Shale	18″
		Coal	8″

Sample from two benches representing the whole bed, with slaty coal of the roof omitted. Collected April, 1905.

Analysis by S. D. Averill.

Moisture	3.55
Volatile combustible matter	34.29
Fixed carbon	54.40
Ash, yellowish white	7.76
	100.00
Sulphur	.71
Specific gravity	1.260

The above sample was taken near the Martin and Johnson County line.

Section of coal 55 feet below the Richardson seam on Whitehouse Creek.

Clay 1′ to massive sandstone.

Coal	18″
Clay	9″
Coal	26″

Note: This is correlated with the Lower Clarion of West Virginia.

Section of Van Harliss Coal (C), Scaffold Lick Fk.

Coal	14″
Bone coal	1½″
Coal	29″

Samples for analysis were taken from openings on Scaffold Lick above bed 755 on Beech Fork where the thickness was 44 inches.

Analysis.	Van Harliss	Beech Fork
Moisture	2.86	3.52
Volatile combustible matter	30.58	27.28
Fixed carbon	58.56	61.20
Ash	8.00	8.00
	100.00	100.00
Sulphur	0.549	0.522

Note: This coal has been identified as the Winifrede of West Virginia in this report.

Section of lower coal at Sam'l Morris, Jr., mouth of Ash Branch of Wolf Creek.

Shaly sandstone.

Coal	32″
Shale	1′ to 1½″
Coal	4″ to 5″
Shale	8′
Coal	26″
under clay	

"The Warfield coal No. 1 probably has its representatives in the two beds at base of section at Ash Branch and also the Peter Cave Creek section."

Analysis of cut shows:

Moisture	2.20
Volatile combustible matter	32.28
Fixed carbon	48.
Ash	17.

"The analysis shows an unexpected percentage of ash."

Note: This has been identified as the Limestone coal in this report and correlates with the Chilton and West Virginia. The Warfield coal is 250 to 300 feet under drainage here, due to its being carried down by the Wolf Creek syncline. Professor Crandall was misled by the interval having increased a great deal between the Warfield coal and the Peach Orchard, due to a thickening of the Upper Pottsville Series. The Warfield seldom if ever has a shale parting, and never has that high percentage of ash, while the Chilton often does.

"The chemical composition of this (Broas) coal is shown in part by the following analysis made for the Survey; samples taken near the outcrop."

Locality	Elev. above Tide	Thick. in in.	Moisture	Vol. Comb. matter.	Fixed carbon	Ash	Sul.
Big Hol. Br.	960	52	3.08	27.70	60.40	8.80	0.430
Honey Br.	915	71	4.20	27.40	58.70	8.70	0.308
Road Fork	910	85	3.29	39.40	47.53	9.72	0.730

Note: These samples were all taken from the head of Middle Fork from the Broas coal which correlates with the Stockton of West Virginia.

"At the head of Scaffold Lick an entry was driven nearly 100 feet (into the Richardson coal), showing the following bed section."

Coal	13 inches
Shale	6 "
Coal	67 "
Shale	26 "
Coal	36 "
	146 inches

"From this entry a column was cut for the Louisville and New Orleans Exposition."

Note: A section of this same coal was made on Wolf Pen Fork of Nats Creek and taken to the Centennial Exposition. It is the famous seam that tourists ride for miles to see. When opened in its fullness, one can easily ride a horse in it without stooping.

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GEOLOGY OF MORGAN COUNTY
KENTUCKY

BY

L. C. Robinson

Assistant Geologist

GEOLOGY OF MORGAN COUNTY

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Introduction

Morgan County was organized in 1822 out of territory taken from Floyd and Bath Counties, and was named after General Daniel Morgan, a revolutionary soldier and officer. The United States Geological Survey has mapped the southern part of the county and the Kentucky Geological Survey has mapped the rest. That portion that lies south of 38° north and west of 83° W. longitude is on the Salyersville Quadrangle, mapped on a scale of approximately two miles to the inch. The portion lying north of 38° N. is on a road and stream map, while the part lying east of 83° W. is on the Prestonburg Quadrangle.

Morgan County, lying entirely within the boundaries of the Eastern coal fields, is bounded on the west by Wolfe, Menifee and Rowan Counties, on the north by Rowan and Elliott Counties, on the east by Lawrence and Johnson Counties, and to the south are Magoffin and Wolfe Counties.

West Liberty, the county seat, lies in the center of the county, and may be reached by bus from Mt. Sterling. Two railroads enter Morgan County, the Morehead and North Fork and the Ohio and Kentucky. The M. & N. F., connecting with the Chesapeake and Ohio at Morehead, operates along the North Fork of the Licking River in the northern part of the county from the western county line as far east as Redwine, and from there south to Lennox. The O. & Ky. enters from the south at the headwaters of Caney Creek and operates down the valley of this creek as far north as the Licking River; it connects with the Louisville & Nashville at Jackson. These two railroads are connected by bus lines operating through West Liberty from Index, on the O. & Ky., to Wrigley, on the M. & N. F. The roads throughout most of the county are dirt roads, very good in dry weather, but practically impassable in wet weather, except for teams. There are also steep, rocky grades which make it difficult for automobiles and heavy traffic. However, the county will be bisected by a new State Highway which will extend east-west across the central part. Except for surfacing, this highway has been completed from the western line to West Liberty; when completed, it will connect with the main automobile trails to the east and west.

Morgan County contains over 240,000 acres, most of which are under cultivation; it is probably one of the best farming counties in the Eastern Kentucky Coal Fields. In addition to garden truck, the farmers raise corn and tobacco, and occasionally fruit. Most of the farms are progressive, and with the assistance of the County Agent many of them are being operated efficiently.

The county is sparsely populated. West Liberty, with a population of about 400, is the largest community. However, it has most of the comforts of a larger town, with running water, electric lights, etc. Wrigley, on the M. & N. F. and Cannel City on the O. & Ky., have hotel accommodations also.

Before the lumbering industry had stripped the hills, trees of all kinds known to Eastern Kentucky (oak, hickory, ash, pine, beech, walnut and poplar, the leading species) could be found. Because of this wonderful stand the lumbering industry was once well developed here, and in some of the valleys the remains of the logging railroads may yet be seen. As most of the desirable timber has been removed the county has turned to coal mining and to farming.

The coals of Morgan County are, for the most part, rather thin, and at the present time there is not much demand for them. They are used locally with success and several companies are actively engaged in mining and shipping coal.

With the exception of the pool on the Caney Anticline at Cannel City, Morgan County does not seem blessed with an abundance of oil and gas. The territory to the north of Caney and to the south of the North Fork of the Licking River has been thoroughly prospected without much success. Locally some gas has been found in paying quantities.

The Licking River was navigable for small boats and rafts until the material washed from the deforested hillsides filled the channel with shifting bars and shoals.

FIELD METHODS.

The portion of the county which has been mapped topographically was mapped by E. C. Barnard and Albert Pike for the U. S. G. S. in 1889 and 1897. A road and stream map of the area to the north of the Salyersville Quadrangle was made by A. B. Williams in the spring of 1925. The only geologic report of this county is in the preliminary report of Morgan, Johnson, Magoffin, and Floyd Counties, by A. R. Crandall, in which he limits himself to a discussion of the coals.

Prof. A. M. Miller has been exceedingly helpful in the preparation of this reconnaissance report and map, by permitting the use of data gathered by him and in discussing various problems which arose during the field work.

During six weeks of the summer of 1925 the author gathered data on the outcrops and coal elevations. Bench marks were established by plane table and barometer readings and radiating from these bench marks, elevations were placed on the fire-clay coal by use of the barometer.

The author wishes to acknowledge the assistance of Mr. J. S. Hudnall, who spent four days in the field helping him to familiarize himself with the stratigraphy, of Dr. W. R. Jillson, who furnished him all the facilities of the Kentucky Geological Survey, and of Mr. E. Cowles, for whole-hearted co-operation in the field. Dr. Collier, of West Liberty, permitted the use of his office and furnished many valuable well logs and accurate maps, together with surveys of many coal beds and prospect pits. Credit will be given by footnote to the several authors to whom the writer will refer in the body of the report.

TOPOGRAPHY

The Licking River and its tributaries take care of the drainage of Morgan County, and a characteristic topography has been developed in each case where the valleys have been cut in different kinds of rock. The relief varies from 300 to 500 feet, with only one or two elevations rising conspicuously above the average height of the hilltops. The lowest point, elevation 695 feet, is that where the Licking River leaves the county.

The highest is at the headwaters of Big Mandy Creek just south of Redwine, where Redwine Hill rises well above 1,500 feet.

The Licking River is the main stream draining Morgan County; its major tributaries are North Fork and Elk Fork. Minor tributaries of this drainage system are Caney Creek, Minor Fork and Devils Fork in the northern part of the county. Blackwater, Grassy, Caney, and White Oak Creeks drain the major portion of the county south of the North Fork of the Licking River. In the extreme eastern part there are a few streams draining into the Big Sandy district. The gradient of all the large streams is low, that of the Licking averaging about one foot to the mile.

This district is a part of the "Mountain Section" and is, for the most part, a maturely dissected plateau. The area south of the North Fork and east of Blackwater Creek is decidedly mature. The valleys are U-shaped with well developed flood plains; the divides are narrow and irregular. To the north of the North Fork and east of Blackwater Creek the valleys are narrow, V-shaped, and in some places bordered by frowning cliffs; the divides are comparatively wide and flat.

The topography is closely related to the geology. The regional dip is to the east and southeast along the western edge of the county, and this causes a succession of widely different rocks to outcrop. In the western part of the county the valleys have been cut in the upper part of Mississippian rocks, mainly in limestones and some shales. The hills are capped with the Pottsville conglomerate. A little further east the massive conglomerate drops towards the drainage level and becomes the predominant rock, instead of merely capping the hills, giving rise to a characteristic topography of deep, steep-walled valleys and broad divides. This in turn gives place to the topography developed in the softer shales, coals, and sandstones of the Pennsylvanian that overlies the conglomerate as the cliff-forming sandstones go under drainage. Toward the eastern part of the county the conglomerate again comes into prominence, having been brought nearer the surface by the Paint Creek Uplift[1].

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[1] "The Paint Creek Uplift." E. O. Rhodes, Dept. of Geology and Forestry of Kentucky, Series V, Vol. 1, No. 3, p. 243.

About 150 to 300 feet of Waverly is shown in the Licking Valley in the western part of the county, overlain by about 50 feet of shale. The conglomerate has a maximum thickness of 200 feet and is separated from the Mississippian limestones by about 50 feet of shale and a thin seam of coal. The belt in which these rocks are exposed is rather narrow because the southeastward dip carries them rapidly below drainage, the conglomerate going under near the mouth of Elk Fork of the Licking River. To the east and south of the conglomerate outcrop the Pennsylvanian formations overlying, make up the entire thickness of the hills, and as the conglomerate is considerably below drainage at some places, a large section of the coal measure is exposed.

GEOLOGY

Stratigraphy

The rocks exposed at the surface in Morgan County are all sedimentary, and, with the exception of the recent alluvial deposits and some quartzite pebbles, range in age from upper Mississippian to the middle of the Pennsylvanian. They consist for the most part of sandstones, shales, and coals. With the exception of the Mississippian limestones, the limestones present are poorly developed. Those rocks which are older than the Waverly (Mississippian) are known only through drilling operations.

GENERALIZED GEOLOGIC COLUMN

System	Series	Formations
Cretaceous	Middle or lower	Quartzite pebbles
Pennsylvanian	Allegheny Pottsville	East Lynn Alternating Sandstones Shales and Coals Conglomerate
Mississippian	Chester St. Louis-Ste. Gene. Waverly	Shales and Limestone Big Lime Shales and Sandstone

GENERALIZED GEOLOGIC COLUMN

System	Series	Formations
Devonian	Senecan	Black Shale
	Ulsterian	Onondagan Limestone "Corniferous"
Silurian	Niagaran	Shale

As stated above, the principal exposures are those of the Upper Mississippian and Lower Pennsylvanian. Knowledge of the older rocks is limited to that which can be obtained from a study of well cuttings.

SILURIAN ROCKS

The only Silurian formation that has been penetrated by the drill in Morgan County is a red shale, probably Niagaran in age. It undoubtedly underlies the entire county and is found wherever the drill has gone through the overlying Devonian limestone.

DEVONIAN ROCKS

Onondagan (Corniferous)

At the base of the Devonian is the Onondagan, a rather thick, cherty limestone, alternately sandy and shaly, known to the drillers as the "Corniferous" and sometimes called the "Irving" sand. Other names for this formation are Ragland, Menifee, Cannel City, and Campton. It is the most productiive oil horizon in eastern Kentucky and possibly in the State.

In general it is a cherty, magnesian limestone, and where oil is obtained, rather porous, due to solution, dolomitization, or both It rises towards the northwestern part of the county because of the regional dip to the southeast. At Cannel City, in the southern part of the county, it lies at an average depth of 1,750 feet.

BLACK SHALE

Overlying and resting directly upon the Onondagan limestone, perhaps conformably, is a series of shales and thin sandstones averaging about 350 feet in thickness. It is the most easily recognized horizon in eastern Kentucky, and is correlated in part at least, with the Genesee and Ohio Black Shale. In Kentucky, however, it is known simply as the "Black Shale." It outcrops along the western edge of the eastern coal field to the northwest of Morgan County and due to the dip of the rocks rapidly drops below the surface until it lies at a depth of 1,100 feet under Morgan County. It is petroliferous and nearly always gassy in streaks, but it can not be considered as an important oil horizon.

MISSISSIPPIAN ROCKS

WAVERLY

The Waverly series underly most of Morgan County. There is one exception; in the northwestern part of the county the section shows about 150 feet of Pennsylvanian, about 75 feet of Mississippian limestone and about 16 feet of Waverlian. In this exposure the rocks are made of bluish sandstones and shales; in the upper part are a few limetone lenses showing that a period of clearer water was approaching.

The Waverly, as a whole, is made up of several hundred feet of shales and sandstones. At the base of this series is found two petroliferous horizons, neither of which is important in this region. The lower, and basal member of this series of shales and sandstones is the Berea Grit. It is a fairly coarse, porous sandstone attaining a thickness of about 30 feet. Overlying the Berea, and separated from it by about 15 feet of shale, Sunbury, is the Weir sand.

The Weir sand is generally a medium fine, gray siliceous sandstone averaging 20 feet in thickness. This formation underlies the whole of Morgan County but seems to be too thin for commercial production of oil. Like the rest of the formations, it thins to the northwest.

Overlying the Waverly series are the Ste. Genevieve-St. Louis limestones, commonly known as the "Big Lime." They are called "Greenbrier" elsewhere and are correlated with the Newman and Mountain limestones of adjacent states. The Big Lime outcrops along the northwestern border of Morgan County, but the southeastern dip carries it rapidly below the surface, so that in the central and southern part of the county it lies between 360 and 460 feet deep. Where it is exposed it is a rather coarse, fossiliferous limestone, which is capable of forming rather steep-walled valleys.

The uppermost representatives of the Mississippian series consist of a limestone member, called by the drillers "Little Lime." This limestone and the sands and shales over it belong to the Chester group or, as it is sometimes called, the Mauch Chunk. In the northwestern part of the county, where these rocks are exposed at the surface, they attain a thickness of about 50 feet.

PENNSYLVANIAN ROCKS

POTTSVILLE

The dominant surface rocks of Morgan County belong to the lower Pennsylvanian, or Pottsville. The Pottsville is present as a series of massive sandstones, shales and coals. It is dominantly sandstone, although the shales in some places attain considerable thickness, and the coals locally become thick enough to be profitably worked.

POTTSVILLE CONGLOMERATE

The lowest, or basal member, is a typical conglomerate, a massive sandstone containing many quartz pebbles. This conglomerate has an average thickness of 180 feet and where it is exposed it develops steep cliffs, narrow valleys, and broad uplands; where it sinks below drainage it holds up comparatively wide floodplains.

CAMPBELLS CREEK LIMESTONE

Seventy feet above the top of the basal conglomerate and separated from it by two thin coals (Lily and Lower Elkhorn), some shales and thin sandstones, is the lowest of the few limestone formations that are found in the Pennsylvanian in this county. The Campbells Creek limestone, is a thin, sparingly fossiliferous limestone containing some rather large concretions.

VANLEAR COAL

Between the Campbells Creek limestone and the Dingus limestone, which is, vertically, about 90 feet higher in the column, appear several shales, sandstones and coals. The most noteworthy of these is the VanLear coal, which is present over most of the county in two seams having a thickness ranging from 16 to 30 inches. Where exposed the VanLear coal makes an excellent key horizon.

Dingus Limestone

The Dingus limestone and its underlying Amburgy coal make another very good key bed. The Dingus is fossiliferous and is an easily recognized formation, primarily because of the fossils. It varies in its mineral characteristics over comparatively small horizontal distances. In some localities (for instance, at Long Branch just northwest of West Liberty) it is so sandy that it is impossible to differentiate it from the overlying and underlying sandstones. It changes in color at various places in the county. In some places it is a light gray, in others, a yellow, and still in others a black, but it never loses its fossiliferous character.

Kendrick Shale

The Kendrick is present in Morgan County as a non-fossiliferous shale horizon about 50 feet thick.

Fossil Lime

Overlying the Kendrick shale and separated from it by 75 feet of sandstones, shales, and coal, lies the so-called "Fossil Lime," a fossiliferous, calcareous formation that is extensively distributed over the southern and central part of the county. To the east, north, and west, the structure of the underlying rock carries it high in the air until it is lost above the hilltops.

Peach Orchard Sandstone

Overlying the Fossil Lime is a cliff-forming sandstone member that is well developed in those parts of the county in which the Fossil Lime is found. It is a rather dense, fine-grained sandstone.

HOMEWOOD SANDSTONE

The Homewood sandstone and the Richardson coal (found near the top of this member) cap the Pottsville in Morgan County. The Homewood is a fine-grained, micaceous sandstone, resistant enough to weathering to form cliffs where it is present on hilltops.

ALLEGHENY

EAST LYNN CONGLOMERATE

The only representative of the Allegheny that was observed was the basal member which is called the East Lynn Conglomerate. It is a true conglomerate and where it caps the hills is cliff-forming.

CRETACEOUS[1]

The Cretaceous deposits in this region are the quartzite pebbles, which may be found in the present stream channels and on the ridges. These pebbles and cobblestones are well rounded and have the appearance of having been transported long distances by water. The parent rock is probably the quartzite ridges to the southeast.

STRUCTURAL GEOLOGY

In this report the expression "Structural Geology" is used to describe the attitude or position of the rocks with reference to a horizontal plane. The rocks of Morgan County, limestones, shales, coals, and sandstones, are all sedimentary in origin, and were originally horizontal, or essentially in that position. Following deposition of the materials that now make up these rocks, forces were developed in the outer part of the earth which exerted pressure on them, folded them into anticlines and synclines, and, where the rocks were weak, or brittle, or where the forces were intense, faulted them. It may be taken for granted that flat-lying rocks have nearly always suffered broadscale warping, although locally no dip may be present.

The methods that are generally used to portray structure are: (1) structure sections; and (2) structure contours.

Structure sections show the attitude of the different beds as they would appear in the side of a deep trench cut across the country along the line of the section. The disadvantage lies in the fact that the structure is shown along a single line only, and therefore merely gives a suggestion as to what the structure might be off the line of the section.

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[1] Jillson, W. R., "Major Drainage Modifications of Big Sandy River." Presented before Ky. Acad. Sci., May 5, 1925.

However, by the use of structure contours it is possible to show the structure of the entire area. Structure contours are lines drawn through points of equal elevation above some chosen datum plane, usually mean sea level, on some easily recognized key or reference bed. Structure contours show the size and shape of the folds, or crenulations, of the surface of the key bed as they would appear if the overlying material could be stripped away.

The key bed used in mapping the structure of Morgan County is the fire clay coal; the contour interval (the vertical distance between adjacent contours) is ten feet. From the structure contours the magnitude and direction of dip can readily be determined from the map. If the thickness between the key bed and the formations above and below it were uniform throughout the county, the structure determined for the reference bed would apply equally well to the other formations. Because of the thickening of the beds in the direction of the regional dip, the structure as shown reflects the conditions that exist underground instead of portraying them exactly.

The usefulness of structure contours depends upon the accuracy with which the elevations were determined. In contouring a bed that is concealed by overlying rocks, the sources of error are many, but if a great many outcrops can be found and the elevations determined accurately, the error in the location of the contours may be very small.

General Statement

In appearance the structure of Morgan County might be likened to a boat with the prow pointing north and the stern lying in an east-west line across the southern part of the area. This appearance is due to the regional dip to the southeast, interrupted through the eastern part of the county by the Paint Creek Uplift which trends in a general north-south direction, and by the Caney anticline on the south. The major portion of the county is, therefore, an irregularly shaped structural basin, modified locally by folds of varying degrees of intensity. The southern part of the county is also marked by two well developed faults that parallel each other in an east-west direction, the Paint Creek to the north and the Johnson Creek fault to the south. To the north of the Paint Creek fault the structure shows a distinct north-south trend, while to the south of the fault the structure shows an equally well developed east-west trend. There have been at least two periods of folding throughout this region; the north-south features developed first; following that the forces became dominant that were responsible for the east-west structure. Where the crenulations developed by these two distinct sets of stresses cross each other, domes or basins are made.

In Morgan County there are one large and one small anticline, one large and three small domes, and one small and two large basins. The anticlines are (1) The Caney Anticline; (2) West Liberty Anticline; the domes: (1) The Jeptha Dome, (2) West Bend Dome, (3) Mize Dome, and (4) Omer Dome; the basins: (1) Spaws Creek Basin, (2) Index Basin, (3) Smith Creek Basin.

CANEY ANTICLINE

This structure[1] was discovered by Prof. A. R. Crandall of the Kentucky Geological Survey in the eighties of the last century, and was early recognized as one of the most typical anticlines in the State. It is in the southern part of the county, the crest lying about one-half mile north of Caney, and striking northeast. It is a pronounced structure throughout its course in Morgan County and has a structural fall of 230 feet. It is terminated abruptly on the north by the Paint Creek fault; to the south it flattens out gradually in a series of small terraces.

WEST LIBERTY ANTICLINE

This is a north-south fold lying in the central part of the county; it separates the two large basins mentioned above. Its crest is slightly crescentic with the horns pointing east, and lies just to the east of the town of West Liberty. It is about ten miles long and three miles wide at a maximum, and has a structural fall of 160 feet. It is terminated on the south by the Paint Creek fault and to the north it passes into a terrace on the flank of an eastward dipping monocline.

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[1] Oral communication. A. M. Miller.

JEPTHA DOME

This large dome lies in the eastern part of the county and occupies an area of approximately 60 square miles; it has a closure of nearly 50 feet. It is elongated in a northerly direction and is the western phase of the Paint Creek Uplift.

WEST BEND DOME

This is a small structure lying about two miles north of the West Bend postoffice, on the Licking River. It is nearly a mile in diameter and has a closure of between ten and twenty feet.

MIZE DOME

The Mize Dome is an elongated dome about three-quarters of a mile wide, with its highest point just southeast of Mize postoffice. Its height is between ten and twenty feet; its northeast axis is about two miles long.

OMER DOME

This is an elliptical structure about one mile south of Omer postoffice. Its long axis lies northeast-southwest and the short axis lies at right angles to the longer one. Its dimensions are three and one-half by one and one-half miles, with a closure of more than forty feet.

SPAWS CREEK BASIN

This is the largest synclinal basin in the county. It lies just to the west of Jeptha Dome and east of the West Liberty Anticline. It extends for a distance of fifteen miles in a north-south direction and is about four miles wide just south of West Liberty. Where War Creek enters the Licking River the basin divides into two branches; one depression extends towards the southeast as far as the Paint Creek fault; in the other the axis is practically due north and south extending up the valley of White Oak Creek to the Paint Creek fault. From the map it may be seen that this basin has a closure of from twenty to forty feet.

INDEX BASIN

The Index Basin is the second largest depression in this region. It lies west of, next to, and parallel with the West Liberty Anticline. It has a length of eight miles along its north-south axis and is about two and one-half miles at its widest. It has a closure of from ten to twenty feet.

SMITH CREEK BASIN

This is a small depression on the eastern flank of the Jeptha Dome in the extreme eastern part of the county. It is a shallow elongated basin; its north-south axis has a length of four and one-half miles and its east-west axis is one and one-half miles long.

PAINT CREEK FAULT

One of the important structural features of this area is the Paint Creek fault, a normal fault. It enters Morgan County to the east just south of the point at which Rockhouse Creek crosses the county line. It follows the course of the creek to the Licking River and then continues southwest to Lewis Station on the O. & Ky. R. R. The trace of the fault continues a little south of west and leaves the county about one-half mile northwest of Daysboro. Throughout its entire course in this county the fault parallels the Caney Anticline. The fault plane is not exposed at any of the stations visited, but the effects are too obvious to overlook. To the north and south of the fault plane, the rocks are steeply inclined and crumpled. The effect of the fault on drainage lines is also well marked. The normal drainage pattern for this region is decidedly dendritic, but wherever the fault is present the streams follow the fault plane. The upthrow side of this fault is to the north and the vertical displacement varies from twenty feet on the east to one hundred fifty feet on the west.

JOHNSON CREEK FAULT

This normal fault cuts across the southern tip of the county about three miles north of the southern extremity. It parallels the Caney Anticline and the Paint Creek Fault. Like the Paint Creek fault it has the upthrow side to the north. The maximum displacement in this county is found where the fault crosses the western county line, at which intersection there is a vertical displacement of eighty feet.

HISTORICAL GEOLOGY

The geologic history, as can be interpreted from the rocks in this district is limited to the Paleozoic and post Paleozoic. (The only rocks exposed at the surface in Morgan County are upper Paleozoic and later. Information regarding formations older than the upper Mississippian must be obtained from distant outcrops or from well cuttings; in this county wells have not yet penetrated below the upper part of the middle Silurian, or Niagaran.)

All the rocks in Morgan County are sedimentary; moreover, they were deposited by water. Those of the Paleozoic Era are marine formations; that is, they were deposited in or under sea water. These rocks contain a record, more or less complete, of the sedimentation that took place from the middle of the Silurian to the beginning of the Pennsylvanian; they also contain a record of the conditions that existed on the land masses that furnished the material for their formation. By a knowledge of conditions under which certain classes of rocks are formed, it is possible to obtain a fairly accurate idea of the geography, or distribution of land and water, and the topography of the land masses which existed when these rocks in this area were formed.

When the Paleozoic sediments were laid down, an interior sea extended over that part of North America which lies west of the Blue Ridge Mountains, from the Gulf of Mexico to Canada, probably as far as the Gulf of the St. Lawrence. The land mass which lay east of this broad inland sea is called Appalachia. This land of Appalachia underwent many fluctuations during

Paleozoic times, and the sea to the west saw many changes. Cool water gave place to warm; deep water to shallow and vice versa; clear water became muddy and then clear again.

As stated above, the oldest rocks exposed in this region are those of the upper Mississippian. The record of this area before upper Mississippian times, as read from well cuttings, is that of alternating submergence beneath the sea and emergence from the sea. The oldest rock penetrated by the drill is a limy shale that was deposited in middle Silurian seas. The material represents the waste of some land mass, the position of which is not certain. If the Cincinnati Arch was formed before this time and was an island in the middle Silurian Seas, it could have been the source.

Overlying the Silurian shale is a limestone which is called the Onondagan, or Corniferous, of middle Devonian Age. The lower Devonian and upper Silurian are missing in this county and were either never deposited or were deposited and then eroded before the Onandagan was laid down. In either case there is the evidence that this region was a land mass while the unconformity between the Silurian and Devonian formations was developed. The sea during Onandagan time must have been clear, shallow water in order to have had limestone deposited; this means that the land mass which supplied the materials was either far away or so low that coarse material could not be brought into the sea by the streams that drained the surrounding lands. Following the deposition of the Onandagan limestone the area suffered a slight uplift. This is recorded in the slight unconformity between the middle Devonian limestone and the upper Devonian shale, the Black Shale or Genesee, as it is sometimes called. The Devonian sea was becoming more shallow or the land mass Appalachia was being raised a little so that the streams with their increased gradient could bring in the clastic material which makes up the Black Shale.

The interval between the deposition of the Black Shale and the deposition of the overlying Waverly formations was one of erosion, meaning that this region was again above the water. Following this the water encroached upon the region and the Waverly rocks were laid down. The Waverly sea which succeeded the Devonian sea probably covered very much of the same district, but the conditions on the land were such that the sediments deposited were thicker and coarser, beds of sand alternating with beds of shale. This sea gradually deepened until most of the district west of Smoky Mountains and south of Pennsylvania was under water, and limestone was deposited over most of this area. The period was followed by an interval of muddy water, during which some shales and sandstones were deposited. In the eastern part of the county there was apparently some folding toward the end of the Mississippian, which resulted in the elevation of a low island.[1]

The close of the Mississippian and the inauguration of the Pennsylvanian was marked by a wide-spread uplift, followed by erosion. A decided change in the old land of Appalachia must have taken place, for when the sea encroached from the southwest in Pottsville time, immense quantities of sediments were brought in and deposited.

The Pennsylvanian rocks in Morgan County are alternating sandstones and shales. The basal member is a conglomerate characterized by the presence of quartz pebbles which show by their rounded form that they must have been transported great distances by fairly rapid streams. The region must have been at a halting condition some of the time, as evidenced by the presence of coal beds.

A study of coal beds makes it seem possible that they represent vast swamps or marshes in which ancient vegetation flourished. That these swamp conditions changed to deep water and back again to swamps is shown by the interbedded sandstones and shales, with here and there a bed of limestone carrying marine fossils. That these conditions extended on through Pennsylvania times is suggested by the fact that the basal part of the Allegheny, Conemaugh, and Monongahela in the district to the east have lithologically the same characteristics.

Up to the close of the Pennsylvanian the Paleozoic Sea had been receiving sediments derived from the land mass to the east. This sedimentation must have been accompanied by a progressive submergence of the basin in order to accommodate the thousands of feet of material that were deposited there. This subsidence did not have to be continuous, and it undoubtedly was not, evidenced by the character of the sediments and the unconformities which occur between the Silurian and Devonian, the Devonian and Mississippian, the Mississippian and Pennsylvanian, and also the minor unconformities that occur within the various periods. At the close of the Pennsylvanian this region emerged from the sea and so far as is known has been above the sea ever since.

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[1] "A Mauch Chunk Island in the Miss. Seas of E. Ky." W. R. Jillson, Ky. Geol. Survey, Series VI, Vol. 22.

During Paleozoic times diastrophism occurred, wide-spread and locally. The formation of the Cincinnati Arch, and the Paint Creek Uplift were inaugurated before the close of the Paleozoic.

Following the uplift which closed the Paleozoic in this region, and perhaps accompanying it, were the diastrophic movements which developed the series of folds that have been described under "Structure." There were undoubtedly two periods of folding, both of which took place before Comanchean times: First, the development of lateral forces causing the folds with the north-south trend; second, the pressure from the southeast which culminated in the Pine Mountain fault. It is probable that it was during a period of relaxation following this folding and these over-thrust faults, that the normal faults present in Morgan County were developed.

Since the emergence of the land and during the deformation that accompanied and followed it, degradation has been in progress. During the Mesozoic Era the land was comparatively quiescent, and this region was reduced to sea level. It is believed that the concordant summit levels of the hills mark this old peneplain which was developed during late Jurassic or Comanchean times. The reason for dating this period of peneplanation after the folding and faulting is that the plain truncates the folds and faults. Following the Comanchean peneplanation the region was uplifted, the velocity of the streams was increased, enabling them to transport the quartzite pebbles, and the present drainage system was inaugurated.

ECONOMIC GEOLOGY

The mineral resources of Morgan County are coal, clay, road material, building stone, oil, gas, and soils.

COAL

Morgan County lies within the western border of the eastern coal field.

The eastern coal field covers an area of approximately 10,500 square miles and lies in a great structural trough the northwest side of which is the Cincinnati Arch.

Beginning at the base of the Pottsville conglomerate, the first coal bed is found in the shales between the Mississippian limestones and the conglomerate. This is the subcarboniferous coal of previous reports. It does not occur at any place as a workable bed, except for local purposes. It can be found wherever the base of the conglomerate is exposed for more than one or two feet. Because of the regional dip this coal is exposed in the western and northern part of the county; in tracing it south and east it is found to go rapidly below drainage and it is not seen again. Above the conglomerate the coals follow at irregular intervals conforming in a general way to the stratigraphic succession throughout the eastern coal field.

In connection with the brief description of the coals covered by this report the accompanying table will be found helpful in correlating the names used in this report with the names used in other reports on this district and surrounding territory.

In the following discussion only the chief facts concerning these coals will be given. For more detailed information the reader is referred to Bulletin No. 10, Kentucky Geological Survey, by A. R. Crandall, on the "Coals of the Licking Valley Region."

For convenience of local reference the coals will be discussed by drainage regions beginning at the western edge of the county.

THE NORTH FORK OF THE LICKING RIVER REGION

The Lily and Lower Elkhorn coals are present along the

North Fork but at no place are they well enough developed to deserve special mention. Near the head of North Fork the Van-Lear Coal (No. 2 of Crandall) is exposed on both sides of the valley one mile above Blair Fork, nearly sixty feet above the water, showing a thickness of about thirty inches until it goes below drainage near the head. It is a cannel coal.

The Whitesburg coal is opened at several places in this valley about a mile below Redwine postoffice, and it occurs about 85 feet above the Cannel coal under a cliff-forming sandstone. It is also about thirty inches thick.

Elk Fork Valley of the Licking River

The conglomerate goes under drainage just below the mouth of Elk Fork bringing the overlying coals nearer to the drainage surface. The Lily Coal is not present in workable amounts and the most important coal in this valley is the VanLear or No. 2. It extends over Mordecai Creek, Smith Branch, Lick Creek, Rush Branch, and through the divide to North Fork.

This seam ranges from 20 to 46 inches in thickness, the opening on Rush Branch showing 46 inches of cannel coal with a thin slate roof overlain by three inches of ordinary bituminous coal.

The Whitesburg coal has been faced at several prospects showing coal seams ranging up to 48 inches thick.

CANEY CREEK

The Coals of Caney Creek make up the largest continuous area of cannel coal that has been developed in Kentucky. As in the case of North Fork and Elk Fork, the important coal throughout this valley is the Van Lear, or No. 2. The seam varies in thickness from place to place, averaging about 45 inches, of which more than half is cannel coal. Because of the Caney Anticline this coal occurs fairly high in the hills, particularly around Cannel City and Caney.

The Whitesburg and the Fire Clay coals are present, but are not important in this district.

CORRELATION OF EASTERN KENTUCKY COALS

Period	Series	MORGAN COUNTY	Series	BIG SANDY BASIN		KENTUCKY RIVER BASIN		CUMBERLAND RIVER BASIN		Licking River Basin
				Tug Fork	Levisa Fork	North and Middle Forks	South Fork	South Fork and Lower Cumberland	Upper Cumberland	
Pennsylvanian	Pottsville	Richardson	Wise Formation	Richardson	Richardson	Hindman				9
		Homewood		Broas or	Broas	Flag	Flag		Cornett	7
				Stockton						
		Peach Orchard		Peach Orchard	Peach Orchard	Hazard	Hazard			6
		Young		Buffalo Creek	Haddix	Haddix	Haddix			5
		Limestone		Thacker	Limestone	Limestone	Limestone		Pardee	
						Hamlin	Hamlin			
				Fire Clay Rider	Fire Clay Rider	Fire Clay Rider	Fire Clay Rider			
		Fire Clay		Fire Clay or	Fire Clay	Fire Clay	Fire Clay	Dean or	Dean	4
				Chilton				Fire Clay		
				Little Fire						
				Clay or	Little Fire Clay	Little Fire Clay	Little Fire Clay			
				Little Chilton						
		Whitesburg		Whitesburg	Whitesburg	Whitesburg	Whitesburg	Vanderpool		3
		Amburgy				Amburgy	Moore			
		Elkhorn		Alma or	Elkhorn	Elkhorn	Howard	Jellico	Taggart	
				Elkhorn						
		Van Lear		Upper	Van Lear or	No. 2 Elkhorn	Lower Howard	Upper Blue	Collier	2
				Marrowbone	Millers Creek			Gem		
					or Upper					
					Marrowbone					
		Lower Elkhorn			Wayland	No. 1 Elkhorn	Burns	Bacon Creek or		
								Lower Blue		
								Gem		
		Lily		Pond Creek or	Lower Marrow-	Sharon	Manchester or	Lily	Harlan	1
				Warfield	bone or Shelby		Zachariah			
					Gap					

ANALYSIS OF CANEY CREEK COALS (Air-Dried)

Location	Moisture	Vol. com. matter	Fixed Carbon	Ash	Sulphur
Above mouth of Prater Fork ...	1.60	40.00	50.00	8.40	0.549
Brushy Fork	1.36	41.00	45.14	12.00	0.824
Spring Branch ...	1.80	40.40	48.80	9.00	2.710

WEST LIBERTY

In the West Liberty region the eastward dip of the rocks brings the coals nearer drainage, and in the hills around West Liberty the Whitesburg coal becomes the most important. The Van Lear is present with about 1.5 to 2 feet of cannel coal, but the Whitesburg is the better developed. Both of these coals are mined for local use.

WHITE OAK AND JOHNSON CREEKS

Thin coals are exposed all along these creeks. The Lily coal attains a thickness of nearly 20 inches near Lykens post-office; this is the maximum thickness found for this coal in Morgan County.

Other exposures of Coals along these creeks are scarce, although some coals were reported as attaining thicknesses up to four feet.

ROCKHOUSE AND LICK CREEKS

The rocks in the region drained by these streams carry all the coals up to and including the Peach Orchard coal (No. 6). Only one, or possibly two, of these coals attains a thickness of 30 inches or more.

CLAY

All of the clays in Morgan County have been deposited by water, and are therefore sedimentary clays. There are two main types present, those associated with coals and those associated with the Pottsville conglomerate.

The only important clay associated with coals is the fireclay that occurs as a parting in the Fire Clay coal. This parting is so thin that although it is extremely important as an horizon marker, it has no importance commercially.

The clays that occur just below the base of the conglomerate have been referred to by A. F. Crider and H. Ries. According to Crider they belong to the clays of the Olive Hill District.[1]

The exposures of fire clay in this county are limited to that part of the county where the base of the conglomerate is above drainage. Along the North Fork of the Licking between Yocum Creek and Devils Branch the fire clay is absent for the most part, and, according to Crider, when it is present it is of such poor quality as to be practically worthless.[2]

Openings on Bucket, Pretty, Minor and Craney Creeks were visited; the following section is characteristic for these exposures:

Conglomerate sandstone
Coal
Siliceous Claystone
Coal
White to gray flint clay
Semi-hard clay
Siliceous fire clay

The only variations were in the thicknesses.

YOCUM CREEK

This creek enters the North Fork of the Licking opposite Paragon postoffice. Fire clay with a thickness varying between five and nine feet is found along this creek to within half a mile of its head; above this the clay is missing.

PRETTY BRANCH

An opening about one quarter mile up Pretty Branch has uncovered a bed of greenish flint clay.

Other exposures were found on Nans Branch of Yocum

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[1] See Bibliography.

[2] "The Fire Clays of N. E. Kentucky," A. F. Crider, Kentucky Geol. Survey, Series IV, Vol. I, part 2.

Creek showing about five feet of cream colored clay; at the mouth of Blackwater Creek of the Licking River about nine feet of fire clay are exposed.

ROAD MATERIAL AND BUILDING STONE

The only rock in this county that is suitable for building purposes is sandstone, of which there is a large amount. As a rule, this rock will not bear the cost of transportation, but locally it has been used with considerable success in building culverts, chimneys, houses, etc. These sandstones are also suitable for road material.

The limestones which outcrop below the base of the conglomerate and reach a thickness of 75 feet are mainly dark gray and light gray oolitic types, are non-dolomitic, and are practically free from iron. Another limestone which outcrops in western Morgan County is light gray and crystalline. According to Richardson, it is non-dolomitic, free from iron and capable of taking a high polish.[1] It is not only suited for construction work, but is also good for decorative interior work.

OIL AND GAS

Relation of Oil and Gas Accumulation to Structure.

In this county the accumulation of oil and gas is closely related to structure. The Cannel City Pool is clearly associated with the Caney Anticline, and the accumulations of oil and gas to the north of the Paint Creek fault are localized on small domes and terraces.

THE OIL AND GAS-BEARING ROCKS

The only reservoir known to the writer is the porous, sandy limestone, the Onondagan (Corniferous), Devonian in age. The Weir and the Berea, important producing horizons to the east, are thin, yet they attract attention because of the slight show of oil that is noticed when the drill penetrates them.

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[1] "Building Stones of Kentucky," C. H. Richardson, Kentucky Geol. Survey, Series VI, Vol. XI.

In all strata there is considerable variation in composition and texture from place to place and oil sands are not exceptions. Particularly when the "sand" is a limestone and the porosity is due to solution or dolomitization, there is a considerable variation in texture and porosity to be expected. In such a case a well located in a fine-textured spot into which little oil could penetrate, would be dry or would merely exhibit a show of oil. It is not surprising that even when structure and surrounding wells indicate a favorable location some wells should be dry. Then again the Onondagan contains some quartz sand, scattered irregularly through it. The amount and distribution of the sand through the reservoir rock undoubtedly influences the porosity and therefore the accumulation of oil or gas. A dry hole therefore should not be considered a decisive test for a given locality when structural conditions and surrounding territory are indicative of the presence of oil.

No rule can be formulated for the locating of wells in regions where porosity is irregular because the irregularity is due to conditions that existed when the "sand" was deposited or to changes that have taken place since, which are not reflected at the surface. In the case of structure, however, some rules can be formulated.

In the first place the oil and gas accumulated after the structures that are present were developed. Two periods of folding are recorded; the older folds are to the north of the Paint Creek fault and have their longest axes extending in a prevailing north-south direction; the younger folds and faults were developed with their axes trending roughly east-west. The Caney Anticline and the Paint Creek fault are younger than the north-south folds and are older than the accumulations of oil and gas.

In general the oil and gas seem to have moved to their present position from the southeast. A test well should therefore be put down on the south flanks of the east-west folds. If gas is obtained, the next well should be located further south; if salt water is obtained the next location should be located further north. If oil is obtained, wells should be drilled to the east and west. In the case of the north-south folds, the area capable of furnishing oil or gas must be taken into consideration, and wells located so as to obtain a maximum collecting area.

Analysis of Crude Oil—West Liberty.

Laboratory No. G-4247, Petroleum, labeled "crude oil from Corniferous 'sand' 2½ miles east of West Liberty, Morgan County, Ky." Sample a thickish green oil, dark brown by transmitted light.

Specific gravity, .855=33.7° Beaume

	Per cent by volume	
Distillate below 150°C (302°F)	11.10	gasoline fraction
Distillate 150°-300°C (302°-572°F)	34.60	burning oil fraction
Thick green-brown residue	54.40	
Total...............	100.00	

Began to distill at 85°C=185°F

(Analysis by A. M. Peter)

(Signed) A. M. PETER, Chief Chemist.

DEVELOPMENT

The first wells drilled in this county for oil were drilled on the Caney Anticline in 1891, but the price of oil was so low that drilling was abandoned until 1912 when the Kentucky Block Cannel Coal Company, hoping to obtain gas to operate their air compressors, put down a well within the limits of their mining settlement, Cannel City. This well was one of the best ever brought in, in Kentucky. It came in at the rate of 320 barrels a day and during its maximum production it is said to have produced 12,000 barrels a month. Since then many wells have been drilled on the Caney Anticline, most of them producers.

Besides the wells in the Cannel City Pool, there are numerous other oil or gas wells and dry holes drilled throughout the county. Many of them are located on the map, but the total is not represented. It is difficult to obtain the number of wells that have been put down in the county. A number have been drilled by small companies or individuals who failed to obtain oil in commercial amounts and who have left the field; a dry hole is hard to locate.

Some of the important wells are those on Elk Fork near the mouth of Cow Branch. These wells have been furnishing the town of West Liberty with gas for many years. Several wells on West Bend Dome about six miles due west of West Liberty have been good producers of gas.

POSSIBLE AREAS

West Liberty is supplied with gas by several wells drilled in a terrace about three miles northwest of the town. This terrace pinches out to the northwest and south. A well located about one mile up Lick Branch would be on this terrace, and would possibly produce gas and maybe oil. Other locations on this terrace could be made where the terrace crosses Indian Creek and Mordecai Branch.

In the northwestern part of the county thère are two structures that deserve testing; Craney Dome and a structure about one and one-half miles west of Blairs Mill Postoffice.

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INDIAN BURIAL GROUND
FULLERTON, KENTUCKY

BY
Lucien Beckner

INDIAN BURIAL GROUND AT FULLERTON, KENTUCKY

By Lucien Beckner.

About the beginning of August, 1926, grading was begun on some streets as an addition to Fullerton, Greenup County, Kentucky, just across the Ohio River from Portsmouth, Ohio; and with the first few shovels of earth removed signs of an ancient Indian village began to be revealed. Mr. A. T. Pack, in charge of the work, at once telephoned the facts to Dr. W. R. Jillson, Kentucky State Geologist, who sent the writer to investigate and report.

The field being graded consists of about ten acres, six or seven of which seem underlaid with graves; and in the adjoining field, to the west, is another ten acres, the surface of which is as thickly strewed with refuse relics as is the part being graded. A few years ago, in digging the foundations for a house in this western portion, an Indian grave was uncovered, implying that it is also underlaid with graves. During the two days the writer was there one skeleton was found for each 130 yards uncovered by the scrapers, which will give a possible total of 600 interments for the whole town site! Besides there were a number of places that were possibly cremation interments, others that were possibly the graves of infants in which all bones had disappeared, and there were at least two tiers of burials, showing that the location had been used long prior to the coming of those who remains are turned up by the shallow scraping, some of the other remains being buried as deep as six feet. This, therefore, is one of the largest Indian graveyards in Kentucky.

The site is on the first bench above high water, on the west bank of Tygart's Creek, about three quarters of a mile from its junction with the Ohio, and about three miles above the mouth of the Scioto. The north edge of the site is highest, from which the surface terraces northwards towards the Ohio, and slopes southward towards a small branch that runs between it and the base of the river hills. To the east the field drops down to Tygart's Creek making a thirty-foot escarp ment, as steep as the nature of its unconsolidated materials permits. At the base of this escarpment is a fine spring which the natives say was a deer lick. To the west the field slopes gently to the next lower river bench, upon which the Indians perhaps made their cornfields after the spring floods had subsided. Across the creek to the east are other level fields that were perhaps in corn.

Along the south edge of the field the river bluffs rise steeply several hundred feet; altogether a most agreeable place for a town. Tygart's Creek, a small river, large enough for canoes in ancient days, made its citizens a passway through the river bluffs to the hunting lands beyond; the Scioto and Little Scioto gave them water routes to the rich Ohio country to the north, the banks of which were settled by their kindred; and east and west the great Ohio could carry their canoes to unknown distances for hunting, trade, or war. They were in the midst of some of the finest corn lands, the best fishing waters, and the richest hunting grounds on the continent.

Shales and shaly sandstones outcrop on the river cliffs and creek banks just south of the village site, from which they secured paving and hearth flags and abrading stones. From the stream beds they took home many pebbles of thin, flat black shale, thin hard sandstone, chert, and clay ironstone concretions, eroded from the native rocks; and irregularly shaped ones of granite washed out of the glacial deposits, which they used for poundstones, to crack nuts, marrowbones, etc., and from which they fashioned axes, pestles, celts, etc.

None of the graves seen exceeded thirty inches in depth, and most of them were around eighteen inches. They could never have been deep, but the plow has taken much material off of them, possibly as much as is left. One was found later about six feet deep. There was apparently no system in the arrangement of the graves except that they occasionally developed irregular groups, but without suggestion of design. A small mound, so reduced in size that it was not recognized as such until opened by later excavators, revealed several skeletons. This was possibly a communal burial for which the bodies had been collecting for some time in treetops, on scaffolds, or in mortuary "temples." In the single graves bodies were buried in any direction, and in almost any position. There is nothing left to mark a grave site, no stones being used for lining; and, if skins, bark, or logs were used, they have disappeared. The dirt over the bodies was darker than the surrounding clay, because ashes were used as filler, and, perhaps, also because of the humus remaining from the decay of the perishable materials of the shrouds and coffins. This dark material does not extend to the surface, unless in a very shallow grave, and in either event the scraper usually "found" the remains first, and cut off either the feet or skullcap or face, sometimes both. On this account, of the fifteen skeletons unearthed while the writer was present, it was not possible to secure a single perfect skull. The bones are very fragile and much decayed, ribs and the extremities of the larger bones usually dropping to pieces when lifted.

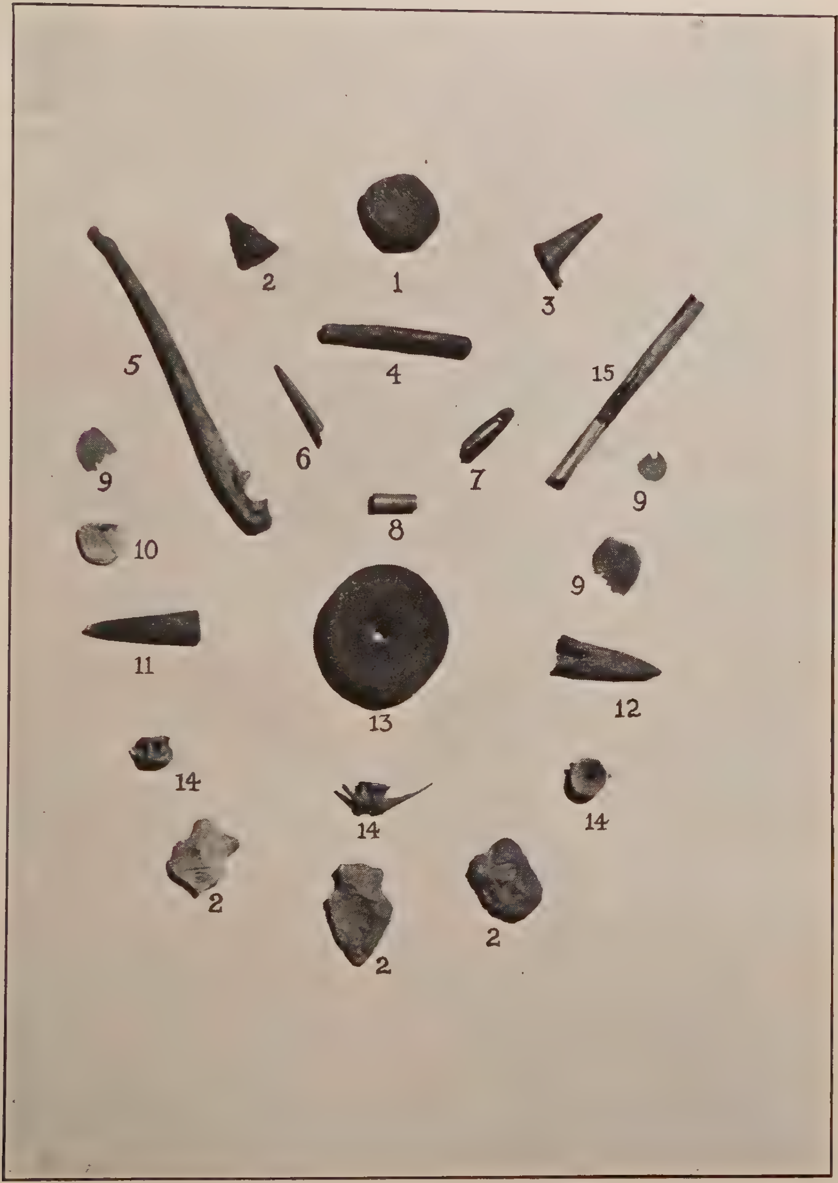
Most of the bodies were flexed, the legs so bent that the foot and hand bones were mixed *on top* of the pelvis, suggesting that the flesh was stripped off before burial. One mandible was found on the left chest, twelve inches out of place. Only one extended burial was observed, but some others were found afterwards. Several of the flexed skeletons were lying on the side, without regard to right and left. So often the feet and cranium were higher than the rest of the body that the impression was made that they had been forced into a hole too small for proper disposition; these were possibly winter burials in empty storage pits, and were invariably covered with ashes. Stone age man was not able to excavate in frozen ground.

At the head of the extended burial was a lump of white quartz crystals from the inside of a geode; at the head of another was a peculiarly shaped clay ironstone concretion. Beads made of bones of birds and mammals, and several perforated teeth of bears; perforated "stones" from the head of the white perch, incised mussel shells; and one or two peculiar pieces of bone that were perhaps nose-ornaments were found in other graves. On the chest of one was a jawbone of the native black snake. It is very probable that further excavations will reveal other and similar characteristics of native burial.

The entire ground is a mass of potsherds and animal bones, and possibly some of these have taken part in the rites, but the most careful observation failed to unquestionably connect either with a burial. Although the pots had been of large size, none of the pieces were larger than the hand and few of them larger than a watch. The animal bones were often charred, sometimes still organized in natural position, as if thrown aside after most of the meat had been cut off, leaving them attached by the ligaments, in which condition they were either buried or got buried accidentally. On none of them were there marks of teeth of dogs or other carnivores. Many shells of the box tortoise were found, and one of them seemed to pertain to a burial, so close was it to the corpse; but it might also have been accidental.

Nothing like post holes was discovered by which an idea of the architecture can be gained; but I was told by Mr. Pack that the day before I arrived the scrapers had unearthed a "tipi site," which consisted of a circular pavement of burnt sandstone flags, about ten feet in diameter. Its location was pointed out to me, about the center of the field, and the hearth stones were still in sight, most of them being piled upon the side of the avenue being graded. They had been burned and were so friable that they broke in handling into fragments hardly larger than one's hand. This suggests the communal house of the southern Indians and the Sioux.

There were also, scattered through the field without order, many cinder heaps that probably were hearth sites. Some of the pebbles may have been used for cooking in their pots which, being made of the usual clay-shell mixture, were not able to endure much contact with the fire. The pots belonged to the eastern types, had handles or "ears;" were decorated outside with incised lines, usually without seeming design; the edges were sometimes scalloped; they were sometimes contracted near the mouth; and the "ears" were of several types, three or four of which were secured. No pipes were found, but one pebble seems to be a "blank" for one, designed to be the simplest type of right angled stone with holes in both



RELICS FOUND AT FULLERTON

1. Abrading stone. 2. Chipped flints. 3. Turkey's spur bone. 4. Nose ornament of whitted bone. 5. Radius of small mammal whittled on and designed for an awl. 6. Point of a broken bone awl. 7. Bear's tooth with hole in it for stringing. 8. Bead made of section of bird's bone. 9. Fish scales four hundred or more years old. 10. Bone from the head of a white perch. 11 and 12. Pieces of antler whittled to a point and hollowed for the reception of a shaft. 13. Perforated discord of red sandstone. 14. Fish vertebrae. 15. Piece of hollow turkey wing bone, used as a turkey caller.

arms. Mussel shells played a large part in their economy as is shown by the great numbers scattered through the ground. No doubt the animals were eaten and the shell used for hoes, scrapers, knives, dishes, spoons, etc. They were found ornamented with incised lines drawn dentate around the margin, with large holes for binding to a hoe handle, and in peculiar shapes that may be due to art. Many flat stones were also shaped for hoes.

The artifacts found were:

Flint: Arrowheads, drillheads, spearheads, knives, saws, scrapers, celts.

Sandstone: Abrading stones, perforated discoid, hearth flags.

Granite: Poundstones, axes, celts, pestles, pot stones (?).

Shale: Pipe (?), hoes, polishers (?).

Bone: Beads, awls, nose bone (?), turkey calls, snake jaw fetish (?), tortoise shell rattles (?), bears' teeth ornaments.

Clay: Pottery (mixed with shells), perforated discoid of a sherd.

Coal: Flat discs (?), small lumps.

Antler: Socketed points, perhaps for fish spears.

Shells: Hoes, scrapers, dishes, ornaments.

The animal remains found included:

Carnivores: Bear, coon, fox.

Herbivores: Elk, deer.

Rodents: Beaver, fieldmice (?).

Birds: Turkey (many spurs and wing bones), grouse (?).

Reptiles: Black snake, box tortoise, snapping turtle (?).

Fish. *Scales,* fins, vertebra, and headstones.

Evidently no orientation of the body was attempted. The backbone of skeleton number 6 laid north 16 east; of number 7, north 60 west; of number 11, north 1 west, etc. The last was extended burial and measured 5 feet, 10 inches from heel to skullcap. As the trowel and whisk-broom began to display the osteology of this man, the big crowd of native sightseers at once began to desclaim on what a giant he was; the opinion was expressed time and again that he must be over six feet, one intelligent man asserting that he believed he was "six feet, six.'' This was such a splendid beginning for a marvel story that I felt a sense of meanness when I shattered it with the measure.

The only pathologic conditions observed were a small cut in the forehead of one skull which had healed, and a number of badly decayed teeth. One piece of mandible of a man in middle age had had a first molar pulled and the bone had healed over completely. All of the mandibles had lost teeth, and one was of a person quite old, the remaining portion very slim, with the foramen mentalis almost on top, and the ascending ramus showing a decidedly large angle. Only two of the skulls saved are in such condition that measurements can be taken of them, one or two others may be later put together and measured. Of the two saved, one is badly deformed with artificial flattening, proving that these people practiced this queer art. The following table gives them alongside of selected measurements from *Skeleton Remains,* Hrdlicka, Bureau of American Ethnology, Bulletin 33:

	N. Dak.	Alton, Ill.	Calaveras	Fullerton	Fullerton
Dia. antero-posterior, max.	19.6	17.8	17.7	17.6	15.8
Diameter, lateral, maximum	13.7	13.5	14.2	14.7	15.8
Cephalic index	69.9	75.8	80.2	83.7	100.0
Basion-bregma height	13.3	13.4	12.3	11.4	...
Diameter, frontal, minimum	9.1	9.6	9.2	9.8	...
Width of orbit	...	...	...	3.65	...
Width between orbits	...	...	...	2.54	...

From the above it will be seen that, not considering the deformed skull, the measurements are nearer in type to the Calaveras skull than to the eastern types represented by the North Dakota and Illinois skulls. This would seem to place these people in the Neo-Amerinds and suggest that their culture was derived from the southwest. They certainly were not Algonquins or Iroquois. The relics found are typically Fort Ancient in culture. About three miles below this burial ground, down the Ohio River, is perhaps the largest prehistoric fort in Kentucky. There was no time to make a thorough inspection of it, but it likely covers fifteen or more acres surrounded by a wall fifteen or twenty feet high. It's connection with the graves, if any, can not be shown; but the works of this character in Ohio are attributed to the people of Fort Ancient culture.

It is possible that these people are historic. The peoples who have occupied this area in historic times are certain Algonquian tribes, Shawnees, Delawares, Miamis, etc., all very recent; certain Iroquoian tribes, Hurons, Cherokees, etc., antedating the Algonquians; Eries, usually classified as Iroquoian, but about whom little is known, except that they disappeared from history in the second and third quarters of the seventeenth century, being driven out by the northern Iroquois, but where to, is still an historic enigma; certain Siouan tribes who fled from the Iroquois at the same time as the Eries, and whose descendants were the Omahas, Arkansas, Quapaws, Osages, etc., and possibly the Catawbas, Biloxi, Ofoes, etc.; and the Mosapelias, shown on Franquelin's map of 1684 as giving their name to a number of villages which had been recently destroyed, but whose ethnic relationship has not been determined. This old map is a monument of what European gunpowder and edged tools did in the hands of the destructive Iroquois, for it shows thirty-three villages of various nations destroyed between the Ohio and the lakes.

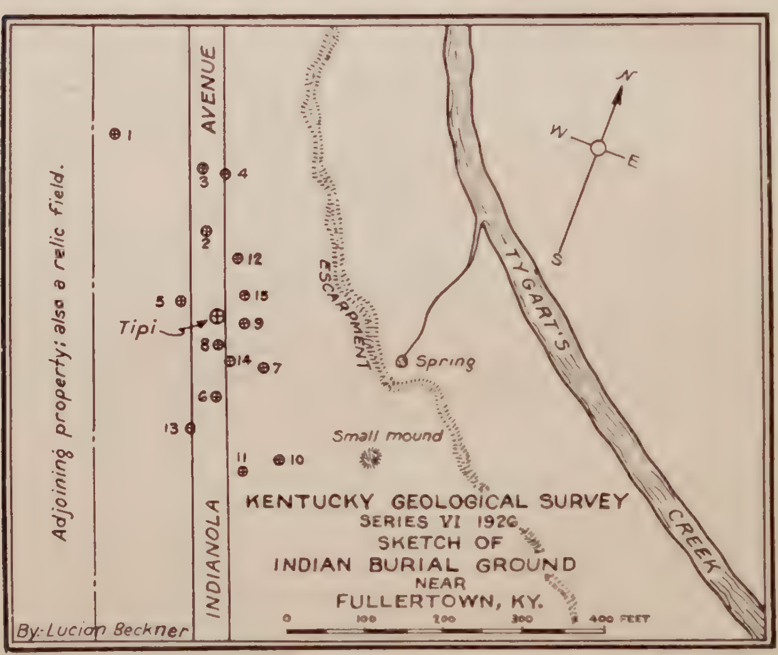
Since the shape of the skull excludes the Algonquian and Iroquoian stocks, we are restricted to the Siouans, Mosapelias and Eries, if the remains are to be deemed historical. When LaSalle was about to make his trip down the Ohio for the first time, a Seneca Chief warned him against the Shawnees and Siouans who lived on the upper Ohio. Franquelin's map was made up from information obtained in large part from LaSalle, yet it does not name any tribes which we are accustomed to consider Siouan; but in the very area described by the Seneca chief it places the Mosapelias, and that is the region where are now found the remains of Fort Ancient culture, seemingly the same people as those at Fullerton. The Seneca chief's warning would alone have made the Siouan stocks historic in that section, but there is much more confirmatory evidence. The names of the Totteroi (Big Sandy) and Kanawha rivers are Siouan; the Omahas and Quapaws tell in their tribal traditions how they formerly lived on the Ohio, describing the Falls at Louisville, and their wars with the Iroquois, and how they dispersed after they reached the mouth of the Ohio, the Omahas going north and the Arkansas or Quapaws going south.

On the earlier maps the Ohio is called the Arkansa River, for instance on Van Keulen's map of New France of 1720, it is named ''River of Ohio otherwise called Acansea sipi,'' but on the same map he names our present Arkansas River ''the River of the Akansa.'' *Sipi* is the Algonquian word for river (and is used in our ''Mississippi''), and shows that Franquelin's information came through Algonquian sources. That both rivers are named Arkansas shows that between the date of La Salle's trip down the Ohio and Van Keulen's map the Siouans had moved down the Ohio and settled near the mouth of the Arkansas where La Salle found them, and where Van Keulen locates a ''village of Kuapa or Acansa.'' On Thevenot's map of 1681 ''Mousouperia'' is located on the east bank of the Mississippi between the mouths of the Ohio and Arkansas Rivers, and one ''Monouperia'' town on the same side but below the mouth of the Arkansas but back from the river, and just opposite the mouth of the Arkansas, and on the Mississippi, a village ''Dakansea.'' If it is remembered that some tribes use ''r'' where others use ''l,'' it will be seen that the ''Mosapelias'' and ''Acanseas'' when they fled from the Ohio settled around the mouth of the Arkansas, and this is the very region where the Ofas, another Siouan tribe, were located in historic times.

Franquelin's map indicates the Ohio and labels it, ''Ohio als Mosopelia als Olighin,'' and the English traders continued to call all of the upper Ohio, even to the Falls, the Allegheny. One of these old maps called the head stream of the Tennessee, ''Peliacipi'' or river of the Pelias; this is the land of the early Catawbas, another Siouan tribe which suggests that ''Pelias'' or ''Perias'' was a generic term and ''Moso'' a descriptive affix; if this is so, the generic name may be the origin of the Biloxi, another Siouan remnant which found asylum on the Gulf coast.

The Siouans are brachycephalic or broad headed as are the

Fullerton people; their eastern branches were known to the Iroquois and Shawnees as "Flatheads" from the curious custom of distorting the cranium, which we found prevalent at Fullerton; the graves of the historic Siouans in North Carolina and Virginia show the Fort Ancient type of culture; the statement of the Seneca chief locates them on the upper Ohio; their own traditions locate them there; the ancient maps show their migration from there, and the identity of names in their old Ohio and new western homes, all point to the probability that our Fullerton people were Mosapelias or Acanseas, and ancestors to the men who ruled the western bank of the Mississippi from the Caddoes in the south to the Crees in the north, from Arkansas to the Canadian border, from 1650 to the coming of the Anglo-Saxon tide of emigration; and who gave their names, names that had once been borne east of the Father of Waters, to the Arkansas, Kansas, perhaps Missouri, and to Biloxi.



MAP OF THE AVENUE BEING OPENED AT FULLERTON AND THE GRAVES FOUND ALONG IT.

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